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Water Quality in the Wapiti-Smoky River System Downstream of the Procter and Gamble Pulp Mill, 1983

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WATER QUALITY IN THE WAPITI - SMOKY RIVER SYSTEM DOWNSTREAM OF THE PROCTER AND GAMBLE PULP MILL, 1983

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ENVIRONMENTAL QUALITY MONITORING BRANCH
ENVIRONMENTAL ASSESSMENT DIVISION
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SUMMARY

Procter and Gamble Cellulose Ltd. operates a bleached kraft pulp mill near Grande Prairie, which discharges effluent to the Wapiti River. In the late 1970's water quality impacts and public complaints began to arise with respect to the Smoky River, into which the Wapiti drains. Since little data were available for the Smoky, a water quality study was carried out in 1983 to assess the impact of the pulp mill and to augment the data base and understanding of the Smoky River system.

The lower Wapiti, the Smoky River, and the Peace River near the Smoky confluence were sampled in March, May, September and November 1983, over a range of river flows. A comprehensive list of physical, chemical, and biotic parameters were included and mill effluents were sampled concurrently.

River flows were near average in 1983, and the mill effluent constituted from 0.2% to 6% of the flow in the Wapiti during sampling occasions. Compared to background quality in the Wapiti and Smoky rivers, the mill's main effluent contained about 2 orders of magnitude higher concentrations of sodium, chloride, colour, phenols, tannin and lignin, chemical oxygen demand, dissolved organic carbon, and fecal coliforms. It was about 1 order of magnitude higher in potassium, sulphate, dissolved solids, biochemical oxygen demand, odour, ammonia,

total kjeldahl nitrogen, total phosphorus, manganese, zinc, and total coliforms, and about 3-5 times higher in calcium, silica, hardness, cadmium, copper, iron, and lead. Trace organic contaminants such as dimethyl sulphides, chlorophenols, chloroform, and chlorinated ethylenes were also present in the effluent. Parameters which increased only slightly or not at all in the effluent included pH, magnesium, bicarbonate, fluoride, alkalinity, nitrite + nitrate, aluminum, beryllium, cobalt, chromium, mercury, molybdenum, nickel, selenium, and vanadium. The mill's storm sewer/cooling water system discharged a much smaller load of contaminants which had no discernible effect on river quality.

River quality downstream was affected by the final effluent in proportion to the parameter increases described above, and in inverse proportion to river flow and dilution. Many constituents increased in concentration in the Wapiti River, were diluted by mixing with the Smoky, but then were fairly constant in concentration downstream until mixing with the Peace River. Exceptions to this pattern were odour, which was difficult to measure, dimethyl sulphides which were not detected in the rivers, and manganese, zinc and bacteria, all of which reverted to background levels more quickly. Oxygen was not markedly affected during the survey. Wastewaters from Grande Prairie entered the Wapiti via the Bear River and may also have affected nitrogen, phosphorus, and bacterial concentrations downstream.

Effluent samples complied with all licence conditions during this study except chemical oxygen demand in the storm sewer/cooling water.

It exceeded limits in 2 of 8 samples but no effect on the river appeared to result. Ten of 21 parameters complied with the Alberta Surface Water Quality Objectives in all river samples, while six exceeded them naturally. Non-compliance in the rivers attributable to the pulp mill effluent was observed for colour, phenols, total phosphorus, and manganese, primarily during low flows. Total coliforms were also non-compliant at times but the pulp mill may not be the sole cause. The remaining parameters complied with the Canadian Water Quality Guidelines or the U.S. Environmental Protection Agency criteria, except for aluminum which exceeded them naturally. Benthic macroinvertebrates in shallow water areas of the Smoky and lower Wapiti rivers appeared to be enriched in numbers and to some extent in taxa as a result of the pulp mill effluent and possibly Grande Prairie wastewaters. The effect was observable downstream to about Watino. Increased colour may counteract this effect, however, and the net effect on biological productivity in the rivers is not known.

The pulp mill effluent may impair the suitability of receiving waters for use as potable supply, because of increases in colour, phenols, manganese, and perhaps odour and bacteria. Recreational capability may be impaired by colour, bacteria, and perhaps odour and benthic growths although Grande Prairie wastewaters may be involved in the bacteria and benthic changes. Direct toxicity to aquatic life did not appear to be occurring. Use for stockwatering could be impaired by odour effects.

STUDY PERSONNEL

The study was designed by T. Reynoldson and J. Kostler and field work was carried out by G. Scammell, A-M. Anderson, M. Soetaert, and D. Dowhaniuk. Water quality samples were analyzed at the Alberta Environmental Centre under the supervision of F. Dieken and D. Smillie. Bacteria were analyzed by Environment Canada (F. Zaal) and the Alberta Provincial Laboratory of Public Health. Algal assays were carried out by T. Ritchie and benthic invertebrate samples and data were analyzed by A-M. Anderson. Data were analyzed and the report prepared by L. Noton, with assistance from A-M. Anderson, G. Scammell, C. Ng, M. Vukadinovic, R. Tchir, J. Kostler, and L. North.

The report was typed by E. Tritthardt, L. Godin and L. Lockhart, and the figures were drafted under the supervision of T. Zenith (Design and Operations Division).

ABBREVIATIONS USED

AGP	Algal growth potential
ASWQO	Alberta Surface Water Quality Objectives
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CWQG	Canadian Water Quality Guidelines
DOC	Dissolved organic carbon
FC	Fecal coliforms (bacteria)
FR	Filterable residue
FS	Fecal streptococci (bacteria)
GC-MS	Gas chromatography - Mass spectrometry
NFR	Non-filterable residue
PCA	Principal components analysis
SPC	Standard plate count (heterotrophic bacteria)
T&L	Tannin and lignin
TC	Total coliforms (bacteria)
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
USEPA	United States Environmental Protection Agency

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1.0 INTRODUCTION

1.1 Background

Procter and Gamble Cellulose Ltd. operates a bleached kraft pulp mill on the Wapiti River south of Grande Prairie, Alberta (Figure 1). The mill commenced operation in 1973 and presently produces about 900 air dried tonnes of pulp per day from a primarily softwood supply. The bleached kraft process involves wood digestion under heat and pressure using chlorine, sodium hydroxide, sodium sulfide, sodium hypochlorite, and chlorine dioxide. The mill draws water for the process from the Wapiti River and the process wastewaters plus plant sanitary wastes are treated via primary clarification, neutralization, a primary settling basin, a ten day aerated biological lagoon, foam retention, and a spill pond. The final effluent is discharged to the Wapiti River through a diffuser. Cooling water combined with clarifier blowdown from the water treatment plant and some plant site runoff (termed the storm sewer/cooling water) is also discharged to the Wapiti River by the Procter and Gamble Mill, about 3 km upstream of the main effluent.

The impact of the Procter and Gamble effluents on the Wapiti River has been assessed in a number of studies by government (e.g. Paetkau and Bishop 1971; Exner and Reynoldson 1976; Alberta Environmental Centre 1987) and by Procter and Gamble. Little effect on river biota was discernible until 1979 when changes in the mill processes occurred. The changes coincided with low flows in winter

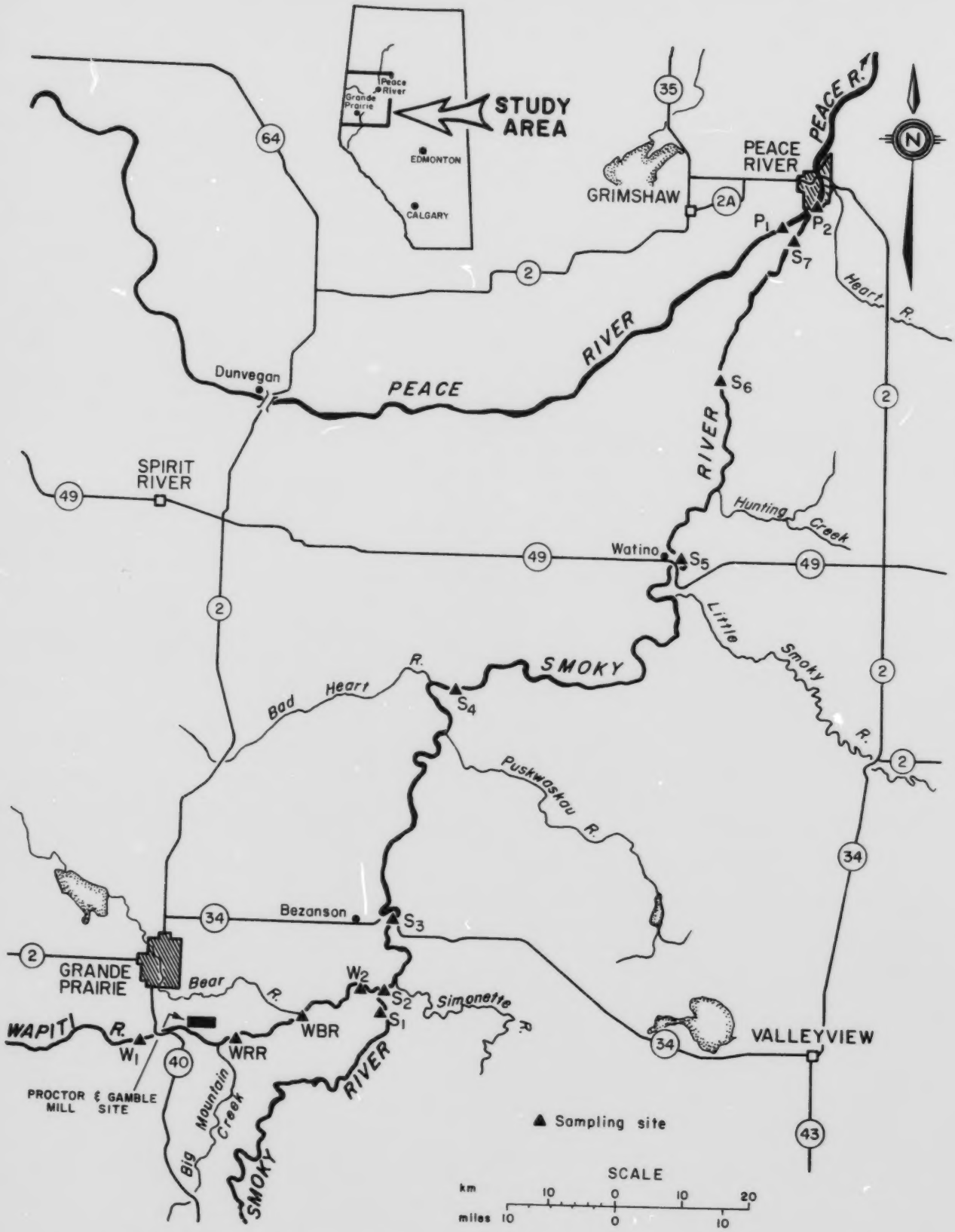

FIGURE 1 THE STUDY AREA.

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1979-80. This caused problems downstream with the quality of the water supply for the town of Peace River, and effects on benthic organisms in the Wapiti River began to appear. Benthic invertebrate and water quality monitoring continued on the Wapiti River, but less investigation had been carried out on the Smoky River, into which the Wapiti drains (Figure 1). Concerns about the Smoky River's quality and its suitability for use began to be expressed by residents along the river. As a result, the Water Quality Control Branch of the Pollution Control Division undertook an investigation of water quality in the Smoky River in 1983 with regard to effects of the pulp mill.

1.2 Objectives

The objectives of this study were to:

- investigate and assess effects of the Procter and Gamble pulp mill on water quality and aquatic biota in the Smoky River; and
- augment the water quality data base for the Smoky River system.

2.0 METHODS

2.1 General

The Wapiti-Smoky-Peace River system was sampled for this study on four occasions in 1983:

15-17 March (ice cover)

10-12 May (open water)

27-29 September (open water)

2-3 November (ice forming)

The times were chosen to include a range of flow and ice conditions. A comprehensive set of physical, chemical, and biotic parameters were sampled in order to permit a broad assessment of water quality in the system. Sampling sites were established throughout the study area, which included the Wapiti River from above the pulp mill to its mouth, the Smoky from just above the Wapiti River confluence to its mouth, and the Peace River upstream and downstream of the Smoky River inflow (Figure 1, Table 1). Access to the sampling sites was by jet boat in May and September and by helicopter in March and November.

2.2 Conventional Water Quality

Samples were collected on the four occasions for several major inorganic, organic, nutrient, and metal parameters. Grab samples were collected in stainless steel buckets, then transferred to appropriate containers, preserved, and returned for analysis at the Alberta Environmental Centre, Vegreville. Parameters, containers, preservation, and analytical methods are listed in Appendix 1.

At the river sites, discrete left bank, right bank, and centre channel samples were collected (Table 1), except at the 'upper' sites W1 and S1 where cross-channel mixing was assumed to be complete and only the channel centre was sampled. During the study, monthly sampling also continued at the long-term network site at Watino (Table 1). On each sampling trip, grab samples were collected on two consecutive days from both the mill final effluent and the storm sewer/cooling water. In May, September, and November, time-integrated

TABLE 1 Sampling locations, 1983

Site	River Km*	NAQUADAT Code	Description
Wapiti River			
W1	44	00AL07GE2010	Wapiti River @ O'Brien Park (Hwy 40)
SS/CW	35	20AL07GE8003	Procter and Gamble, storm sewer effluent grab
FE	32	-8000	Procter and Gamble, final effluent grab
		-8001	Procter and Gamble, final effluent composite
WRR	30	-	At railroad bridge (algal assays only)
WBR	17	-	Above Bear River (algal assays only)
W2	0	00AL07GJ0990	Left - Wapiti River above Smoky River
		- GJ1000	Centre - Wapiti River above Smoky River
		- GJ1010	Right - Wapiti River above Smoky River
		- GJ1020	Composite - Wapiti River above Smoky River
Smoky River			
S1	205	-GF1000	Smoky River, above Wapiti River
-	204		Wapiti River confluence
S2	200	-GF1990	Left - Smoky River, above Simonette River
		-GF2000	Centre - Smoky River, above Simonette River
		-GF2010	Right - Smoky River, above Simonette River
S3	186	-GJ2015	Left - Smoky River at Bezanson Bridge
		-GJ2020	Centre - Smoky River at Bezanson Bridge
		-GJ2025	Right - Smoky River at Bezanson Bridge
S4	135	-GJ2035	Left - Smoky River below Bad Heart River
		-GJ2040	Centre - Smoky River below Bad Heart River
		-GJ2045	Right - Smoky River below Bad Heart River
S5	68	-GJ2055	Left - Smoky River at Watino
		-GJ2060	Centre - Smoky River at Watino
		-GJ2065	Right - Smoky River at Watino
-	68	-GJ0001	Smoky River at Watino. Centre Channel (Long term site)
S6	32	-GJ3995	Left - Smoky River, half way from Watino to mouth
		-GJ4000	Centre - Smoky River, half way from Watino to mouth
		-GJ4005	Right - Smoky River, half way from Watino to mouth
S7	4	-GJ4995	Left - Smoky River near mouth
		-GJ5000	Centre - Smoky River near mouth
		-GJ5005	Right - Smoky River near mouth
Peace River			
P1	930	-FD5000	Peace River, above confluence of Smoky River
-	914	-	Smoky River confluence
P2	908	-HA2040	Left - Peace River at Peace River, above Heart River
		-HA2035	Left centre - Peace River at Peace River, above Heart River
		-HA2038	Right centre - Peace River at Peace River, above Heart River
		-HA2041	Right - Peace River at Peace River, above Heart River

*Distance from respective river mouth, (River Engineering Branch Maps, Alberta Environment)

composite samples were also collected from the final effluent, with a Markland sampler Model #1301. The sampler collects a 60 mL sample every 15 minutes over 24 hours by means of a compressed air pump, plastic tubing, brass elbows, and a 10 L collection vessel. Effluent flow rates were taken from Procter and Gamble monthly reports submitted under Licences to Operate 78-WL-078 and 83-WL-096. Parameter load or flux was calculated as concentration times the total volume of discharge per day, for the location in question.

2.3 Trace Organic Compounds

Samples were collected from the final effluent, and sites W2, S5, and P2 on the four sampling occasions for analysis of trace organic compounds (except P2 in March). Grab samples were collected in laboratory-prepared 1L glass bottles, cooled, and returned to the Alberta Environmental Centre for analysis (Appendix 2). At the river sites the samples were usually composited from left and right bank grab samples. Both volatile (purgeable) and semi-volatile (extractable) trace organic compounds were analyzed by gas chromatography-mass spectrometry (GC-MS). Emphasis was placed on those compounds identified by the United States Environmental Protection Agency as 'priority pollutants' (USEPA 1986) and the analytical technique followed USEPA protocols (Appendices 2 and 10). Extraction or purging was carried out on whole, unfiltered samples such that the dissolved and at least some of the particulate fraction of the target compounds would be recovered.

2.4 Bacteria

Grab samples for bacteriological analysis were collected at the sampling sites on the four survey trips, placed in laboratory prepared glass bottles, cooled, and returned to Edmonton within 24 hours. Samples from the March, May, and September trips were analyzed by the Environmental Protection Service laboratory of Environment Canada (Edmonton) for total coliforms, fecal coliforms, fecal streptococci and heterotrophic bacteria (standard plate count). November samples were analyzed by the Alberta Provincial Laboratory of Public Health, Edmonton. Methods are outlined in Appendix 1.

2.5 Algal Assays

Samples for algal assays were collected in May, September, and November from the regular sites and also from two intermediate sites on the Wapiti River, WRR and WBR (Figure 1). The samples were collected in glass bottles, cooled, and returned to Alberta Environment's Millwoods facility for assaying of the algal growth potential (AGP) of the water.

The AGP assays used standard procedure established by the U.S. Environmental Protection Agency, Environmental Research Laboratory (Miller et al. 1978) and by Alberta Environment (Hamilton et al. 1981). In essence the procedure involves inoculating autoclaved samples in triplicate with the test alga, Selenastrum capricornutum Printz, incubating, and determining the total amount of algae that the samples will produce. This production is then an indicator of the "fertility" of the water.

2.6 Benthic Macroinvertebrates

2.6.1 Field

Benthic macroinvertebrates (zoobenthos) were sampled in May and September on the left and right banks at all the regular river sites in the study area (Figure 1). The habitat sampled was erosional gravel-cobble and was standardized as much as possible between sites with regard to substrate, depth, and current velocity. Five replicate samples were collected at each location with a modified Neill cylinder sampler (area 0.1 m^2) equipped with a collecting net of 0.210 mm mesh aperture. The substrate enclosed within the sampler was thoroughly stirred for 1 minute and larger rocks were individually cleaned into the cylinder. Samples were preserved in the field in 4% formaldehyde.

2.6.2 Laboratory

Zoobenthic samples were stained with Rose Bengal (Mason and Yevich 1967) and strained through sieves with mesh apertures 2 mm and 0.213 mm. Invertebrates in both fractions were then sorted under a dissecting microscope. When the fine fraction contained large numbers of organisms, subsampling was performed using the Imhoff-cone method (Wrona et al. 1982). Specimens were counted and identified according to Bauman et al. (1977), Edmunds et al. (1976), Merritt and Cummins (1978), Pennak (1978) and Wiggins (1977).

2.6.3 Data Analysis

In the benthic data interpretation, a number of variables and data statistics were examined, since a reliance on only one

benthic parameter may lead to misinterpretations. The parameters included abundance, taxonomic composition, and number of taxa, and were analyzed using the techniques described below.

When a benthic community is affected by effluent discharges, changes may occur in the number of taxa and/or the density of organisms. An effluent with a fertilizing effect may increase densities while one with a toxic or inhibitory effect may decrease densities and/or taxa. A simple ordination of benthic sites as to density and taxa (Hocutt, 1975) can help to assess such stresses and compare sites and site groupings in this regard, and was employed here.

Two multivariate techniques, cluster analysis and principal component analysis, were also used by means of the CLUSTAN computer programs (Wishart 1978). Both provide a means of comparing samples using all numerical abundance data for each taxon. Some theoretical considerations and practical applications of these two techniques have been discussed by Gauch and Whittaker (1972), Sinha (1977) and Green (1979).

The cluster analysis involved calculating an index of similarity amongst all possible pairs of sites and grouping the sites into a cluster dendrogram based on their similarity. The index used was squared euclidean distance which takes into account both the kind and number of taxa present. The dendrogram was constructed by progressive fusion of sites from the most to least similar (Ward 1963) such that similar sites group together.

Principal component analysis converts the "m samples by p variables" data set to a "p-by-p" covariance or correlation matrix with a new set of quantitative variables having the following properties (p. 81-82 in Green, 1979):

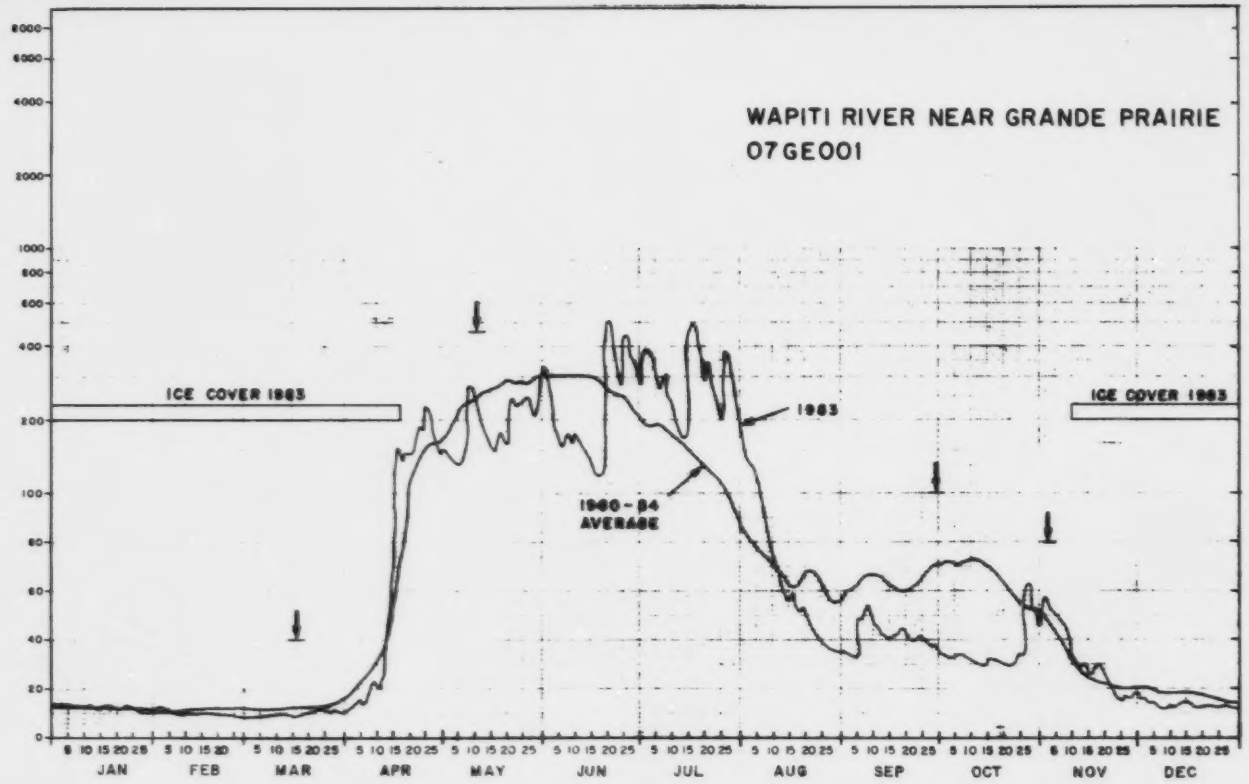
- Each new variable is a linear additive function of the old variables.
- The first new variable extracted is the first principal component and accounts for the largest possible amount of variation in the data set.
- Each additional new variable accounts for the largest possible amount of remaining variation, independent of the previously derived principal components.

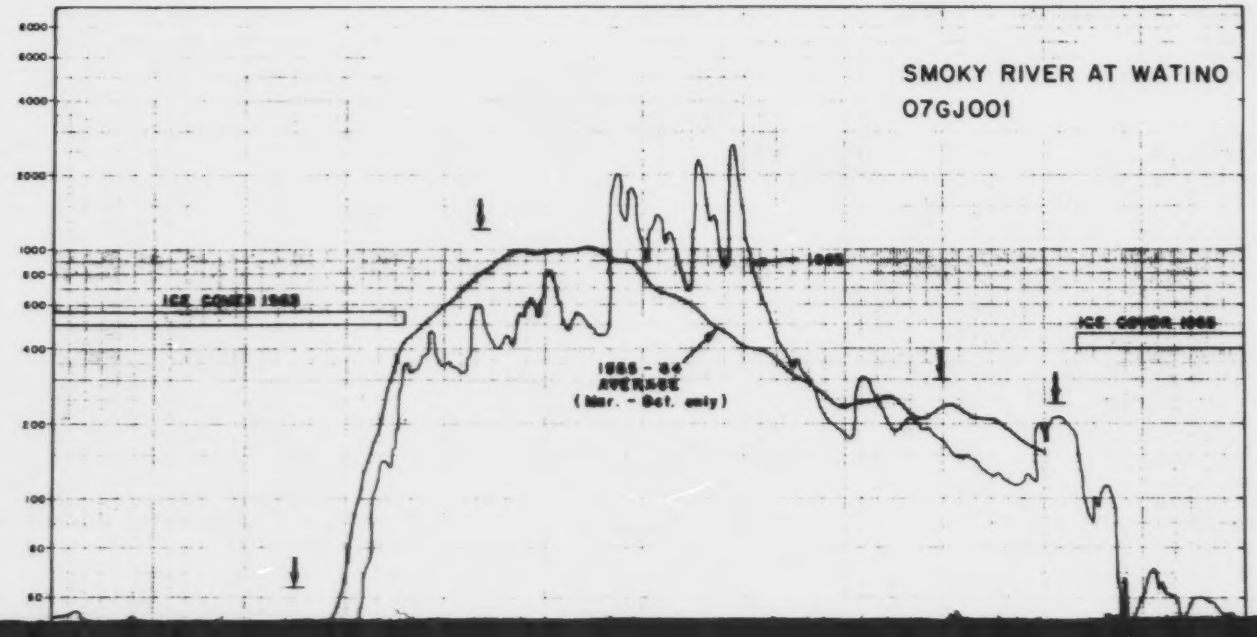
3.0 RESULTS AND DISCUSSION

3.1 Flows and Physical Conditions

3.1.1 River and Effluent Flows

Mean annual flow for 1983 in the Wapiti and Smoky rivers was 87 and 328 $m^3 \cdot s^{-1}$, respectively. Flows in the Wapiti and Smoky rivers in 1983 were somewhat below the long-term average although the Simonette and Little Smoky rivers were somewhat above average (Appendix 3). Most of the sampling in this study was carried out during near-average flows for the date in question, with the exception of the Wapiti in September and the Peace River in March (both below average - Figure 2). After the Wapiti, the Simonette and Little Smoky rivers are the largest tributaries to the Smoky in the study area (Figure 3). Smaller tributaries are the Puskwaskau, Bad Heart, and Bear rivers.





STREAMFLOW (m^3/s)

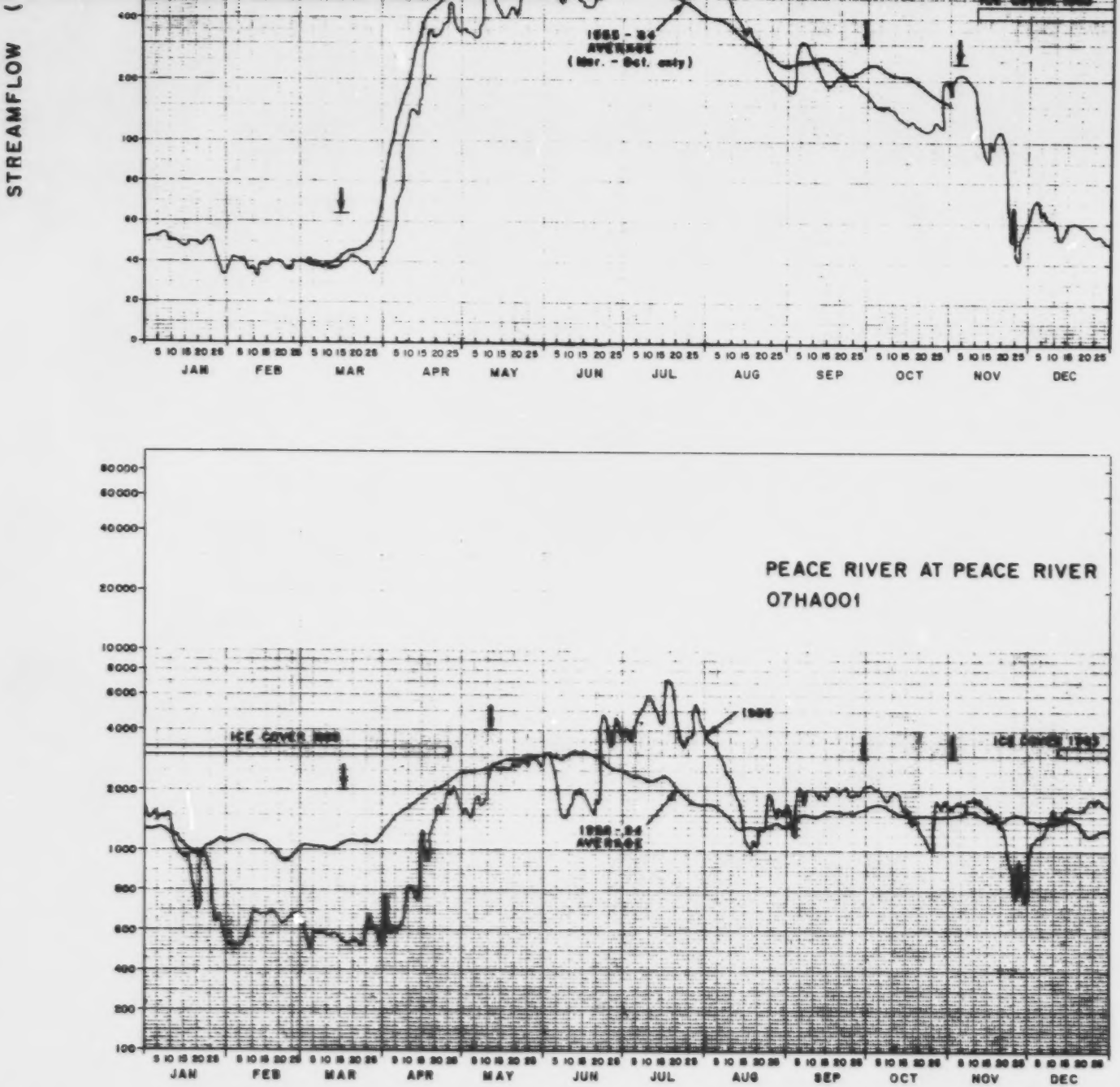


FIGURE 2. RIVER HYDROGRAPHS.

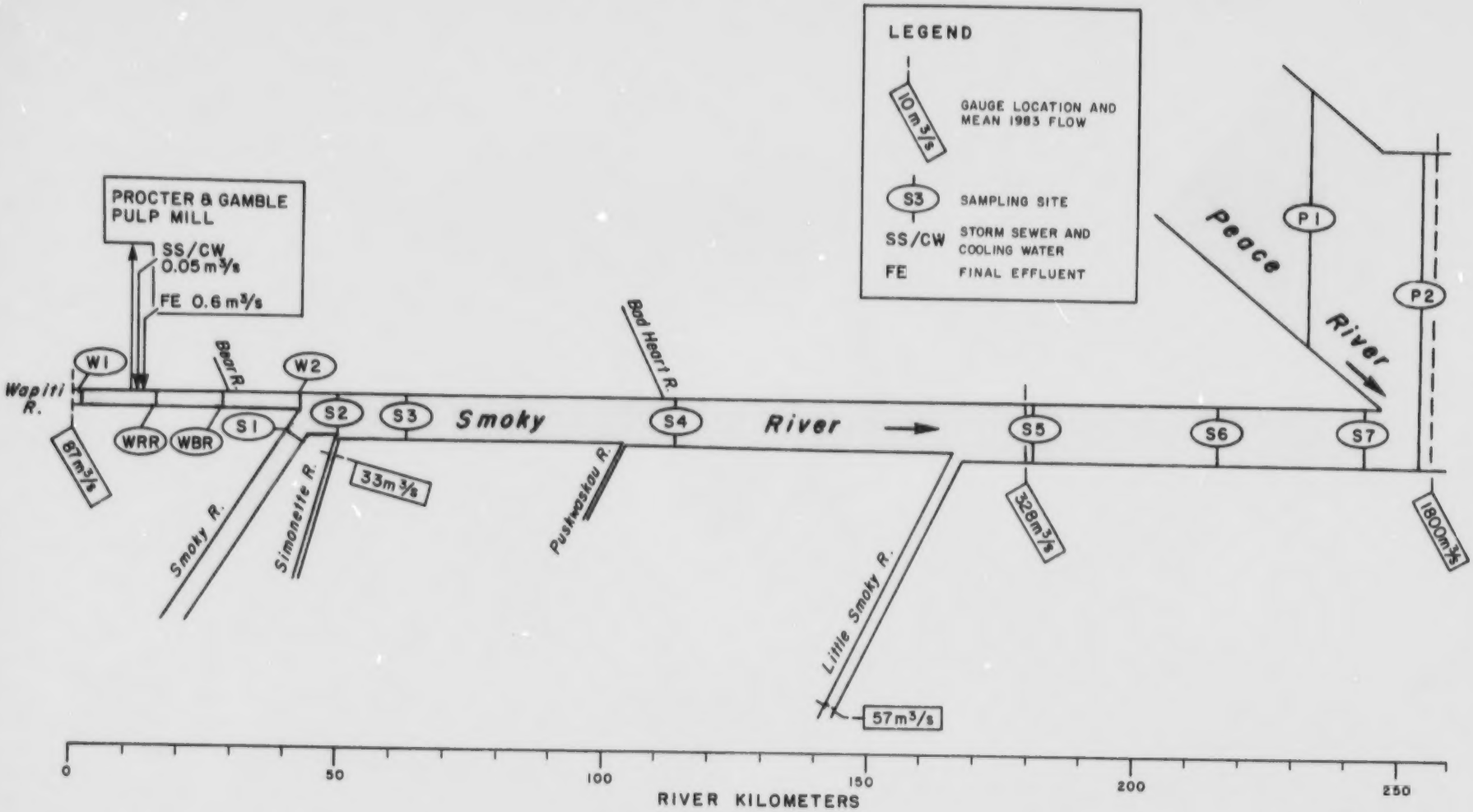


FIGURE 3. RIVER SCHEMATIC

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In 1983, the Procter and Gamble final effluent averaged 0.6 $m^3 \cdot s^{-1}$ and the storm sewer/cooling water discharge averaged 0.05 $m^3 \cdot s^{-1}$ in flow (Figure 3). During the sampling occasions, the final effluent flow as a percentage of Wapiti River flow ranged from 0.2% in May to 6% in March. The storm sewer/cooling water was highly variable in flow since it contains site runoff which responds to snowmelt and rainfall. Other wastewaters in the area were treated municipal effluent and storm sewer discharge, both from the City of Grande Prairie. These wastewaters discharged to the Bear River which enters the Wapiti at about km 16 (Figure 1 and 3). The municipal effluent was released from the secondary treatment lagoons in spring and fall. Neither wastewater was quantified.

3.1.2 Physical Conditions

The Wapiti and Smoky rivers in the study area appear to be fairly typical of foothill rivers, containing much gravel and cobble in their substrate but with areas of finer material (sand and silt) being common as well. From Watino (S5) to near Site S7 on the Smoky (Figure 1), there appears to be a greater abundance of bedrock and boulder, with periodic boulder rapids alternating with flatwater areas. Kellerhals *et al*. (1972) noted that the Smoky around Watino has occasional islands, mid-channel and point bars, an 80 mm median diameter (D_{50}) of bed material, and a river slope of 0.00052. They also noted occasional islands, mid-channel and point bars in the Wapiti around the Highway 40 crossing, and measured a bed material D_{50} of 48 mm and slope of 0.00051.

3.1.3 Transverse Mixing

Effluent or tributary inflows to a river take some distance downstream before they are fully mixed across the channel. The mixing distance varies markedly with discharge, channel geometry, type of inflow, ice cover, and other factors. The mixing length for a point source input on the Wapiti and Smoky rivers under low flow, open water conditions has been estimated at approximately 4 and 10 km, respectively (S. Beltaos, Alberta Research Council, unpublished data). Cross channel water quality sampling in 1983 indicated that of the sampling sites in this study, only Sites S2 and P2 were consistently unmixed. Site S2 is 4 km below the Wapiti River confluence and the left bank there is probably in the Wapiti plume. At Site P2 on the Peace River, the right bank appears to be in the Smoky River plume. This is illustrated by chloride concentrations at the various sites (Table 2). Site S3 13 km downstream of the Simonette River inflow, and Site S5 12 km downstream of the Little Smoky River inflow, varied in terms of transverse homogeneity, being well mixed for inorganic ions and dissolved organic carbon (DOC), but not always well mixed for non-filterable residue (NFR), total Kjeldahl nitrogen (TKN), and total phosphorus (TP - Table 2, Appendices 5 and 6). The latter three parameters are all associated with suspended solids as opposed to the former two which are dissolved.

TABLE 2 Cross channel chloride concentrations, 1983

Site	15-17 March				10-12 May				27-29 September				2-3 November			
	R	C	L		R	C	L		R	C	L		R	C	L	
W1		25				<1				<1				<1		
W2		56			4	4	3		19	19	20		8		8	
S1		<1				<1				<1				<1		
S2	12		45		<1	2	3		5	7	9		2		5	
S3	25		23		2	2	2		6	6	6		3		3	
S4	23		19		2	2	2		5	6	6		3		3	
S5	22		22		2	2	2		4	4	5		3		3	
S6	22		22		2	2	2		4	4	4		2		3	
S7	22		22		2	2	6		5	4	5		3		3	
P1(Comp.)		2				<1				<1				<1		
	R	RC	LC	L	R	RC	LC	L	R	RC	LC	L	R	RC	LC	L
P2	16			<1	2	<1	<1	<1	2	<1	<1	<1	2			<1

Chloride as mg/L
Blanks indicate not sampled.

3.2 Water Quality

3.2.1 Introduction

Complete data for conventional water quality samples collected in this study are placed in Appendix 6. This includes left, right, and centre samples at the river sites, consecutive daily grabs of the effluents, and composite samples of the pulp mill final effluent. In the following sections, left, right and centre data are usually averaged at each site for purposes of presentation, as are the daily effluent grabs for each sampling trip. The effluent grab samples are used for interpretation rather than the composite samples since the latter were not collected on every occasion. Trace organic analyses are in Appendix 7.

3.2.2 Background River Quality

Water quality in the Wapiti and Smoky rivers upstream of the pulp mill was fairly typical of mountain/foothill rivers. The dominant ions were Ca^{++} and HCO_3^-, total alkalinity was in the 100-200 $mg \cdot L^{-1}$ range, total dissolved solids were about 125-300 $mg \cdot L^{-1}$, and non filterable residue increased markedly during periods of high flow (Table 3). Organic compounds were low in concentration and the water was not very coloured. The macro-nutrients nitrogen and phosphorus fluctuated between sampling occasions but, except for phosphorus during spring high flows, were not particularly high. Similarly, metal concentrations were generally low except during May when they increased, likely in association with high flows and high suspended solids. The Smoky River at Site S1 was somewhat higher than the Wapiti in concentrations of $SO_4^=$, Cr, Cu, and Zn (Table 3).

TABLE 3 Background river water quality, 1983

Parameter	Wapiti - Site W1				Smoky - Site S1			
	March	May	September	November	March	May	September	November
pH	8.4	8.2	8.3	8.4	7.9	7.5	8.2	8.4
Ca	58	33	43	43	68	34	42	43
Mg	18	6	11	11	19	8	12	13
Na	25	6	6	4	7	6	5	5
K	1.0	1.2	0.6	0.4	0.1	0.9	0.5	0.5
HCO_3	257	139	182	164	210	135	156	180
Cl	25	<1	<1	<1	<1	<1	<1	<1
SO_4	48	10	23	25	88	21	42	45
SiO_2	4.3	3.4	2.8	2.7	4.2	3.4	2.9	3.1
F	0.12	0.09	0.12	0.08	0.14	0.10	0.09	0.12
T. Hardness	219	107	153	153	248	118	154	161
T. Alkalinity	222	114	149	141	172	111	128	152
Filt. Residue	320	220	180	260	340	250	230	260
T. Dissolved Solids	310	126	174	169	287	137	179	199
Conductance (uS/cm)	561	234	331	317	507	262	333	344
Non-Filt. Residue	20	765	11	14	17	599	10	54
Phenolics	0.003	0.003	<.002	<.002	<.002	0.003	<.002	<.002
BOD	1.6	1.6	<1	<1	<1	1.6	<1	<1
COD	43.7	64.2	<5	7.9	8.5	66.8	<5	10.6
Tannin & Lignin	<.1	1	<.1	<.1	<.1	<.1	<.1	<.1
Odour (thresh. no)	1	1	1	1	1	1	1	1
Colour, true (units)	<10	34	6	8	<10	22	4	15
Diss. Organic C	3.5	9.8	1.8	1.5	1.6	5.6	1.2	2.2
$NO_2 + NO_3 - N$	0.40	<.05	<.05	<.05	0.08	<.05	<.05	<.05
$NH_3 - N$	0.120	0.012	0.005	0.008	0.075	0.016	0.005	0.010
T. Kjeldahl N	0.40	1.50	0.12	0.16	0.50	0.75	0.12	0.20
T. Phosphorus	0.030	0.400	<.006	0.016	0.015	0.435	0.010	0.052
Al (extr.)	0.309	6.82	0.07	0.10	0.161	8.58	0.07	0.32
As ($\mu g \cdot L^{-1}$)	-	-	<.2	0.3	-	-	<.2	0.8
Be (extr.)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Cd	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Co	<.001	0.005	<.001	0.002	<.001	0.006	<.001	<.001
Cr^{+6}(diss.)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Cr	0.004	0.014	<.001	<.001	0.005	0.023	0.004	0.006
Cu	0.004	0.019	0.002	<.001	0.003	0.034	0.014	0.022
Fe (extr.)	0.28	0.96	0.13	0.22	0.22	2.51	0.16	0.76
Hg ($\mu g \cdot L^{-1}$)	<.1	<.1	0.9	<.1	<.1	<.1	<.1	<.1
Mn	0.04	0.148	0.011	0.021	0.017	0.148	0.010	0.021
Mo	<.001	0.007	<.001	<.001	<.001	0.009	<.001	<.001
Ni	0.004	0.018	0.005	0.004	0.003	0.026	0.007	0.009
Pb (extr.)	-	0.020	<.003	0.004	-	0.031	<.003	0.004
Se ($\mu g \cdot L^{-1}$)	-	-	<.2	<.2	-	-	<.2	<.2
V	0.003	0.021	0.003	<.002	<.002	0.026	0.004	0.006
Zn	0.005	0.048	0.003	0.003	0.013	0.065	0.012	0.028
Fecal coliforms (#/100mL)	2	10	8	2	<2	<10	<2	9
Total coliforms (#/100mL)	16	500	40	460	34	80	16	350

Values as $mg \cdot L^{-1}$ and metals as total, unless noted.

3.2.3 Effluent Quality

The quality of Procter and Gamble effluents on the sampling occasions in 1983 is summarized for conventional parameters in Table 4. Trace organic constituents are discussed in section 3.2.4.3.2. Compared to background water quality in the Wapiti and Smoky rivers (Table 3), the mill's main emission, the final effluent, contained higher concentrations of a number of parameters, particularly salts, organic compounds, colour, and bacteria (Table 5). Ammonia, TKN, TP, Mn and Zn were also higher, by about an order of magnitude. Some inorganic ions and most metals were not greatly elevated in the final effluent. Sampling in 1981-82 by the Alberta Environmental Centre (1987) revealed generally similar effluent quality. The high concentrations of salts and organic compounds reflect the chemicals used in the milling process and the large volumes of wood being processed.

The high organic content of the final effluent (median DOC-230 $mg \cdot L^{-1}$) is further illustrated by its contribution to the filterable residue, a measure of dissolved solids (Table 4). If it is assumed that DOC has the general formula CH_2O (carbohydrate), then the equivalent median dissolved organic matter would be about 575 $mg \cdot L^{-1}$. This is 18% of the filterable residue of the final effluent while in the rivers upstream of the effluent, organic matter only accounted for about 3-4% of the filterable residue. Note that in the final effluent total dissolved solids (TDS - calculated as the sum of the inorganic ions - median 2559 $mg \cdot L^{-1}$) plus dissolved organic matter (estimated above at 575 $mg \cdot L^{-1}$) amounted to 3134 $mg \cdot L^{-1}$, which closely matched the measured filterable residue (3165 $mg \cdot L^{-1}$).

TABLE 4 Summarized Procter and Gamble effluent quality, 1983

Parameter	Final Effluent					Storm Sewer/Cooling Water				
	March	May	September	November	MEDIAN	March	May	September	November	MEDIAN
pH	7.5	7.1	7.4	7.2	7.5	8.2	7.0	7.8	8.1	8
Ca	257	181	240	154	214	21	46	18	24	22
Mg	18	12	18	15	17	6	7	6	5	7
Na	785	680	730	718	725	11	13	8	12	12
K	13.9	11.0	12.4	21.8	13.5	0.9	1.7	0.8	0.7	0.9
HCO_3	473	287	400	401	400	74	104	77	99	84
Cl	1150	900	1125	723	1015	1	2	1	2	2
SO_4	475	388	365	603	423	48	84	34	37	42
SiO_2	12.2	9.4	11.2	8.9	9.8	3.2	2.2	2.7	3.1	2.9
F	0.15	0.05	0.06	0.08	0.07	0.07	0.06	0.08	0.08	0.08
T. Hardness	717	503	673	447	595	80	142	70	83	80
T. Alkalinity	388	235	328	329	329	62	85	64	82	69
Filt. Residue	2900	2990	3270	2990	3165	195	315	150	130	170
T. Dissolved Solids	2932	2314	2688	2431	2559	127	208	106	130	127
Conductance (uS/cm)	5095	4220	4670	4105	4450	239	357	193	231	239
Non-Filt. Residue	156	212	345	62	208	5	4218	30	7	7
Phenolics	0.507	0.439	0.449	0.163	0.444	<.002	0.009	0.002	0.002	0.002
BOD	66	45	45	35	45	<1	5	1.4	<1	<1
COD	1119	815	987	715	912	<5	272	8	26	9
Tannin & Lignin	117	90	130	78	104	<.1	49	<.1	<.1	<.1
Odour (thresh. no.)	10	55	10	1	10	1	1	1	1	1
Colour, true (units)	4275	3835	-	3075	3810	<10	15	2	5	9
Diss. Organic C	271	210	257	193	230	1.2	11.2	0.6	0.8	1.2
$NO_2 + NO_3 - N$	0.14	0.12	<.05	<.05	0.07	<.05	<.05	<.05	<.05	<.05
$NH_3 - N$	0.16	0.185	0.064	0.016	0.070	0.058	0.084	0.017	0.036	0.056
T. Kjeldahl N	9.5	6.15	8.75	12.5	9.25	0.15	4.88	0.28	1.05	0.31
T. Phosphorus	1.75	0.8	1.42	0.95	1.10	0.009	1.70	0.026	0.154	0.027
Al (extr.)	0.859	0.479	1.93	0.934	0.777	0.312	77.3	0.218	2.60	0.394
As ($\mu g \cdot L^{-1}$)	-	-	1.0	1.2	1.2	-	-	0.3	1.6	0.3
Be (extr.)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Cd	0.001	0.001	0.004	0.003	0.003	<.001	0.003	<.001	0.001	<.001
Co	<.001	<.001	<.001	0.001	<.001	<.001	0.031	<.001	0.002	<.001
Cr^{+6} (diss.)	-	<.001	<.001	-	<.001	<.001	<.001	<.001	<.001	<.001
Cr	0.014	0.009	0.016	0.26	0.017	0.003	0.056	0.004	0.010	0.007
Cu	0.020	0.015	0.037	0.030	0.022	0.004	0.081	0.026	0.015	0.019
Fe (extr.)	0.81	0.57	1.12	1.90	0.96	0.05	3.98	0.13	1.29	0.135
Hg ($\mu g \cdot L^{-1}$)	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Mn	0.494	0.488	0.870	0.455	0.512	<.008	0.752	0.039	0.097	0.051
Mo	<.001	<.001	0.006	0.006	0.002	<.001	0.062	0.003	0.004	0.003
Ni	0.02	0.011	0.021	0.020	0.014	<.001	0.082	0.008	0.012	0.013
Pb (extr.)	0.002	<.003	0.024	0.026	0.022	<.003	0.181	0.003	0.018	0.005
Se ($\mu g \cdot L^{-1}$)	-	-	<.2	<.2	<.2	-	-	<.2	<.2	<.2
V	0.002	<.002	0.005	0.004	0.003	<.002	0.094	<.002	0.006	<.002
Zn	0.088	0.069	0.143	0.116	0.101	<.001	0.224	0.017	0.020	0.019
Fecal coliforms (#/100mL)	505	108	2600	2	310	<2	142	<2	55	2
Total coliforms (#/100mL)	1050	3050	32,500	120,000	3,400	2	250	2	278	10

Values as $mg \cdot L^{-1}$ and metals as total, unless noted. Monthly values are means of 2 grabs.
Medians are calculated from all values (usually 8).

TABLE 5 Parameter concentration in final effluent (FE) compared to background river (BR) concentrations

Approximate ratio, FE:BR			
<3	3-5	5-50	50-500
pH	Ca	K	Na
Mg	SiO_2	SO_4	Cl
HCO_3	Hardness	Filt. Residue	Phenolics
F	Cd	T. diss. Solids	COD
Alkalinity	Cu	Conductance	Tannin & Lignin
NO_2+NO_3-N	Fe (extr.)	BOD	Colour
Al (extr.)	Pb (extr.)	Odour	Diss. organic C
Be (extr.)		NH_3-N	Fecal coliforms
Co		T. Kjeldahl N	
Cr^{+6} (diss.)		Total P	
Cr		Mn	
Hg		Zn	
Mo		Total coliforms	
Ni			
Se			
V			

Non-filterable residue is too variable to characterize.

During the course of the study, organic parameters such as DOC, phenols, and colour tended to decline, metals as a whole seemed to increase somewhat, while other inorganic parameters were relatively constant in the final effluent (Table 4).

The pulp mill's storm sewer/cooling water effluent was generally much lower in volume (Appendix 4) and more dilute in concentration than the final effluent (Table 4). However, it was much more variable in quality, with several organic and inorganic parameters being very high in May. The variability likely reflects storm runoff from the plant site and the discharge of alum sludge in May (allowed under licence). Non-filterable residue (NFR) was high in May (4218 $mg \cdot L^{-1}$), as were Al (77 $mg \cdot L^{-1}$) and $SO_4^{=}$ (84 $mg \cdot L^{-1}$). Despite occasional high concentrations of some parameters, this effluent contributed a much smaller load than the final effluent (Table 6). The effect on river quality is discussed in following sections.

Other wastewaters of potential significance in the study area were treated municipal effluent and storm sewer discharges, both from the city of Grande Prairie. The municipal effluent was released to the Bear River in spring and fall, and urban runoff would have entered the Bear River at various times via Grande Prairie's storm sewer system. Although the city of Grande Prairie sampled their lagoon in spring (Appendix 8), no loading data are available for either of these effluents. Possible effects of these effluents on the Wapiti and Smoky River are discussed in later sections.

TABLE 6 Summarized parameter loadings, 1983

	Estimated Load - $Kg \cdot d^{-1}$					Load Ratios		
Site:	W1	SS/CW	FE	W2	S5	$\frac{W1+SS/CW+FE}{W2}$	$\frac{FE}{W2}$	$\frac{FE}{S5}$
Na	43,100	30	39,100	82,700	201,000	0.99	0.47	0.19
Cl	8,600	4	52,100	54,400	71,500	1.12	0.96	0.73
SO_4	106,000	165	24,700	119,000	522,000	1.10	0.21	0.05
DOC	50,000	6	12,500	60,000	154,000	1.05	0.21	0.08
COD	320,000	130	48,600	434,000	864,000	0.91	0.12	0.06
Phenols	14	0.005	21	31.5	91.0	1.19	0.66	0.23
Tannin & Lignin	4,700	18	5,550	8,000	18,000	1.28	0.69	0.30
Total P	1,910	0.8	65.5	2,610	8,000	0.76	0.03	0.01
Mn	736	0.397	30.8	926	3,046	0.83	0.03	0.01
Zn	232	0.1	5.6	300	1,050	0.79	0.02	0.01

* Mean of the 4 sampling occasions. Discharge taken as equal at W1 and W2.
SS/CW - storm sewer/cooling water
FE - final effluent

3.2.4 Downstream Quality

3.2.4.1 Introduction

Downstream of the pulp mill and the Bear River, increases were measured in a number of water quality parameters. In many cases changes downstream can be related to the concentrations in the pulp mill final effluent. However, the behaviour of individual parameters downstream was variable and depended upon the fate processes acting on them including dilution, transport, sorption, sedimentation, volatilization, biological uptake, and biochemical degradation. These are discussed by parameter group. Compliance is discussed in a subsequent section (3.2.5).

3.2.4.2 Major Ions and Inorganic Parameters

This group may be considered to include pH, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, $SO_4^{=}$, SiO_2, F^{-}, hardness, alkalinity, filterable residue (FR), total dissolved solids (TDS), conductance, non-filterable residue (NFR), and oxygen.

These constituents or parameters are normally present in all surface waters and include the major ions which account for most of the dissolved solids in lakes and rivers. Many are conservative (Na^{+}, Mg^{++}, K^{+}, $SO_4^{=}$, Cl^{-}, FR, TDS, conductance) in the sense that they are dissolved and fairly unreactive. The main processes affecting their fate are dilution and downstream transport. Other parameters may undergo some changes in natural waters, such as pH, Ca^{++}, HCO_3^{-}, alkalinity, and hardness which are all involved in the $CaCO_3$ cycle. Non-filterable residue (NFR) is a measure of suspended solids. It is highly variable in concentration in rivers,

normally increasing with discharge as a result of scouring and suspension of particles in the water (Figure 4).

Na^+, K^+, Cl^-, $SO_4^=$, FR, TDS, Conductance

These major inorganic parameters, were increased 5 times or more in the final effluent compared to background river concentrations (Table 5). Downstream increases in these parameters occurred as a result: increases in Na^+ and Cl^- were greatest in March and September when river discharge was lowest, and least in May when discharge was highest (Figure 5). The longitudinal pattern was an increase at Site W2, then a decrease at S2 as a result of mixing with the more dilute Smoky River, then fairly constant concentrations downstream until a second drop in concentration at site P2 as a result of dilution in the Peace River. This pattern also occurred in TDS, although not as markedly. Sulphate concentrations also increased at W2 but the upstream Smoky River had higher concentrations than the Wapiti. As a result $SO_4^=$ was higher at Site S2 than at W2 (Figure 6) in contrast to Na^+ and Cl^-. Downstream of site S2, $SO_4^=$ was fairly constant or declined gradually, until dilution in the Peace River.

Table 6 indicates that the Proctor and Gamble final effluent accounted for the observed increases in Na^+, Cl^-, and $SO_4^=$ at Site W2, since the sum of the loads at the upstream site, the storm sewer/cooling water, and the final effluent was nearly equal to the load at site W2 downstream. Storm sewer/cooling water loads were only a small fraction of final effluent loads. These ratios also indicate that wastewaters that may have been coming down the Bear River did not

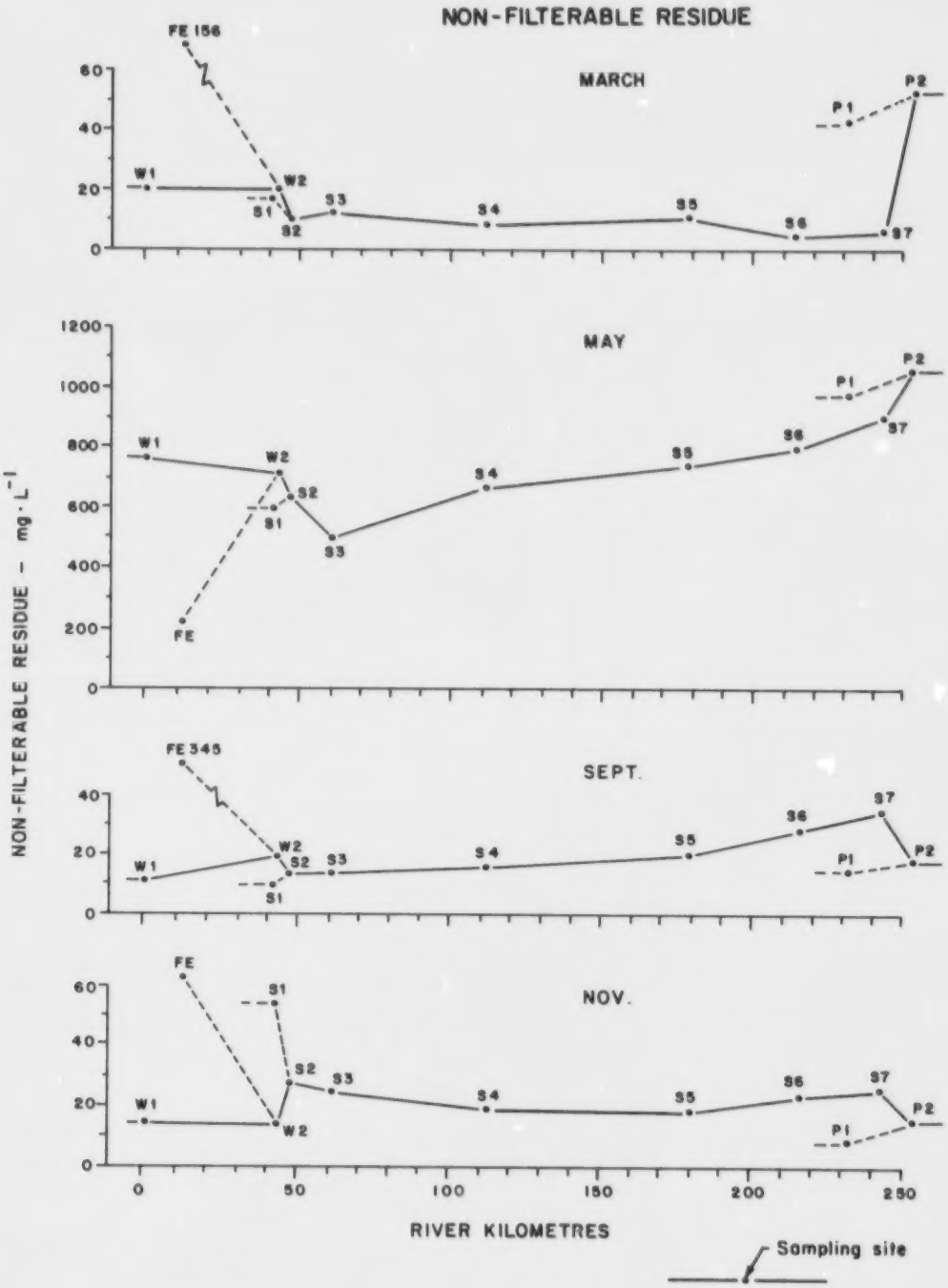

FIGURE 4. NON-FILTERABLE RESIDUE, 1983.

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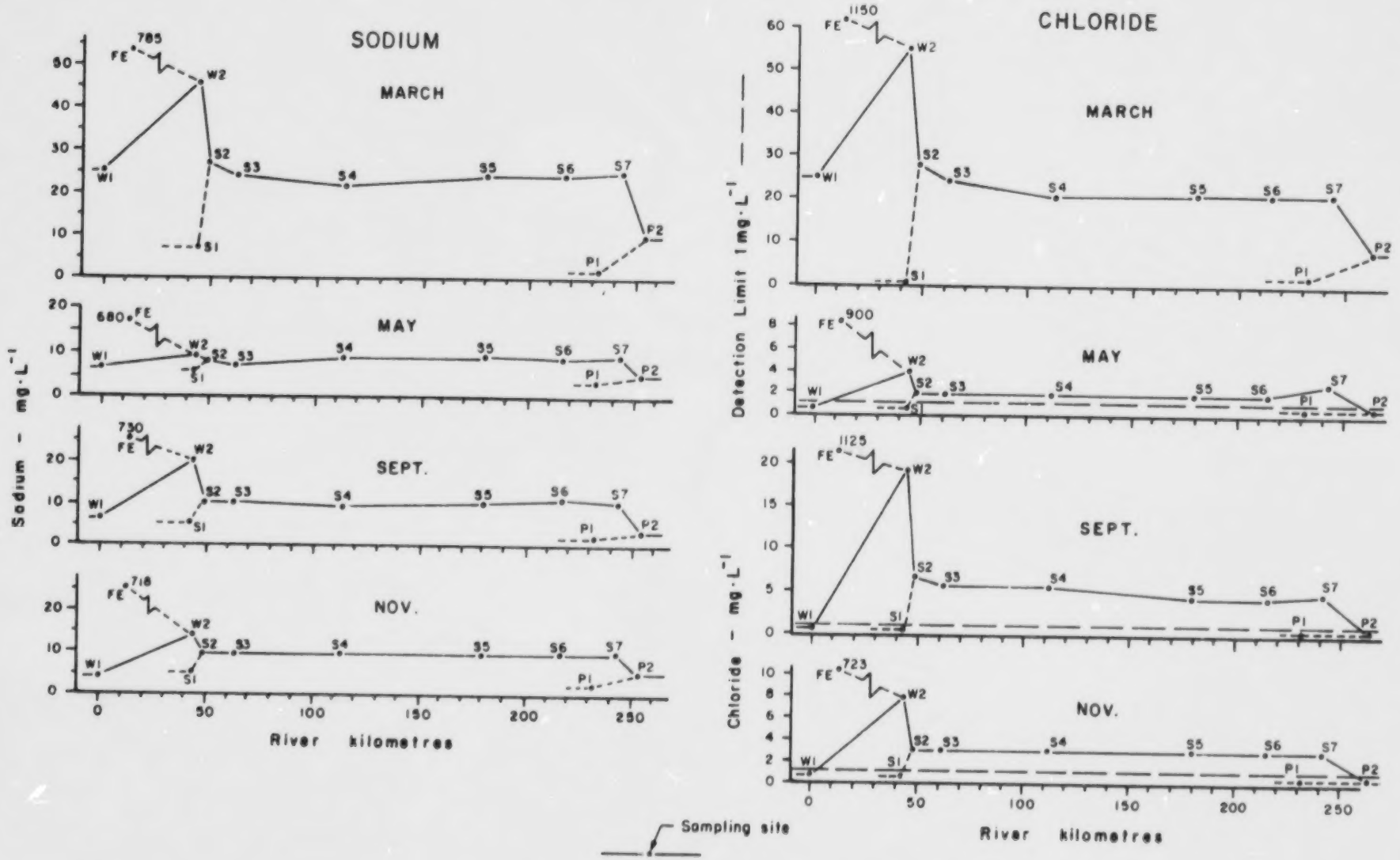

Figure 5. Sodium and Chloride concentrations , 1983.

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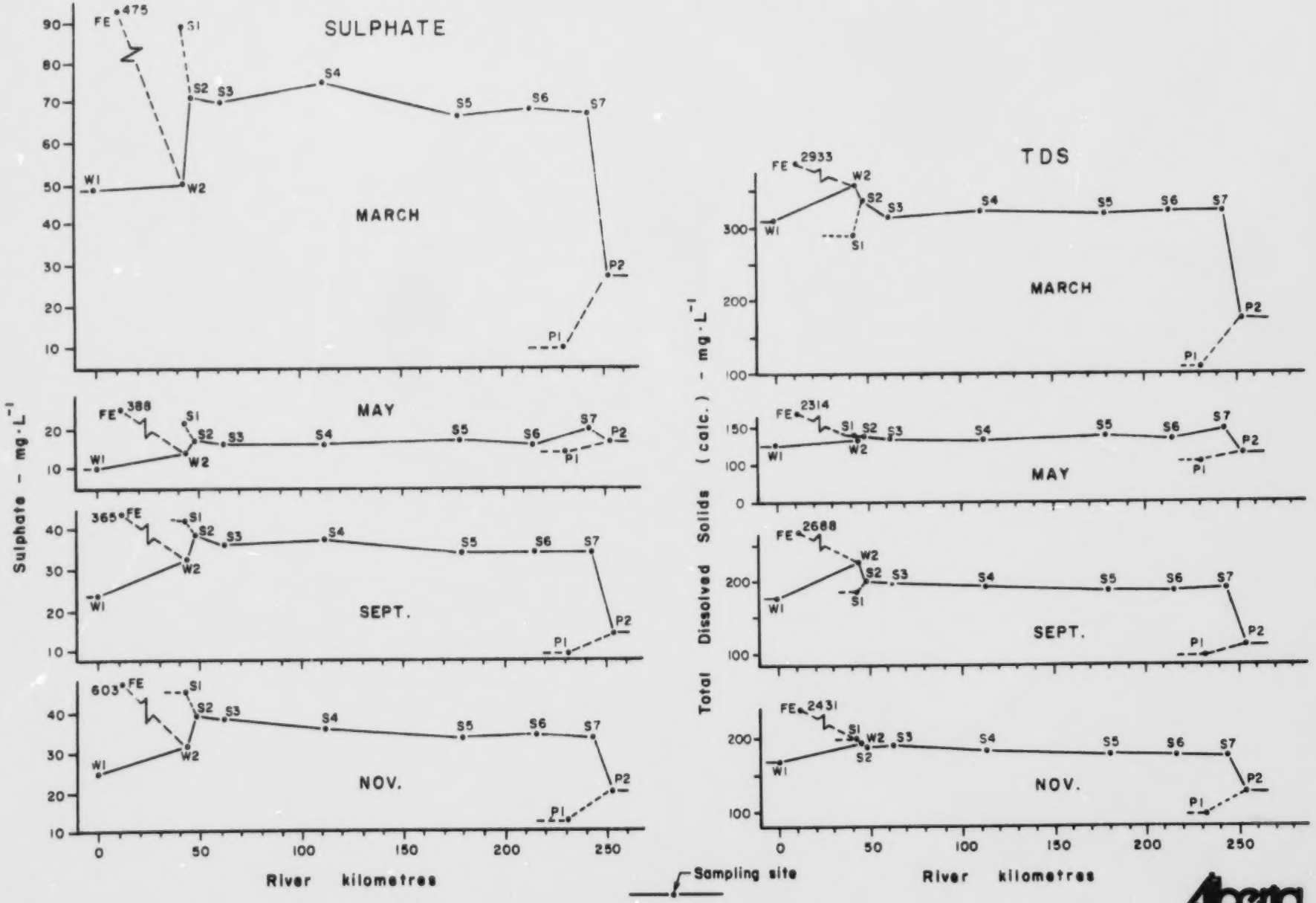

Figure 6. Sulphate and Total Dissolved Solids concentrations , 1983 .

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affect river concentrations of these parameters, at least on these sampling occasions.

Filterable residue and TDS are measures of dissolved solids and will approximate the sum of the various dissolved parameters. TDS was increased by the mill effluent as noted above. Potassium was about 10 times higher in the mill final effluent than in background river samples and some downstream increases were found when river flows were low. However, concentrations were low (approximately 1 $mg \cdot L^{-1}$) all the way down to the Peace River (Appendix 6).

Non-filterable residue

Non filterable residue was quite variable in the rivers but more constant in the final effluent (Figure 4). It was actually lower in the effluent than in the river in May, but higher on the other sampling occasions. Of the latter times, only in September was some increase in NFR observed at Site W2 and attributable to the mill effluent. The storm sewer/cooling water effluent was very high in NFR in May (4218 $mg \cdot L^{-1}$ - Table 4) but the total load from that source was not high enough to affect river concentrations (Figure 4). Under low to moderate flows the final effluent contained about 10 times the concentration of NFR than did the rivers. This appeared to occasionally increase NFR slightly at Site W2 but not farther downstream.

Oxygen

Oxygen measurements were made at the study sites in March and at Site S5 monthly during the ice-covered season (Appendix 9). The data indicate that a gradual downstream decline in oxygen occurred in March of 1983: from about 11 $mg \cdot L^{-1}$ at S1 and W2 to about 9.3 $mg \cdot L^{-1}$ at S7. Marked depletion was not observed and monthly data at Site S5 indicate that winter oxygen was maintained at 11.9 $mg \cdot L^{-1}$ or more that winter. Monthly monitoring by Procter and Gamble, reported to the Pollution Control Division under their License to Operate, indicates that dissolved oxygen at Site W2 was 9.5 $mg \cdot L^{-1}$ or more during the ice-covered period in 1983. During the open season, re-aeration would very likely have maintained oxygen near saturation throughout the river system, as occurred at site S5 (Appendix 9).

Other

The remaining major inorganic parameters (pH, Ca^{+}, Mg^{+}, HCO_3^{-}, SiO_2, F^{-}, hardness, and alkalinity) were not elevated in the final effluent more than about 5 times background river concentrations. No, or very little, effect on these parameters was measured downstream of the pulp mill.

3.2.4.3 Organic Compounds

3.2.4.3.1 Conventional Organic Parameters

This group will be considered to include phenols, tannin and lignin (T & L), biochemical oxygen demand (BOD), chemical oxygen demand (COD), true colour, odour, and dissolved organic carbon (DOC).

These parameters are often sampled in water quality monitoring, and although measurable amounts of them are normally present in natural surface waters, they are usually much higher in treated wastewaters such as from sewage plants and pulp mills. Biochemical oxygen demand, COD, true colour, and odour are not actual compounds, but are normally related to the organic matter present in the water. Biochemical oxygen demand is a measure of the oxygen consumed by readily bio-degradable compounds while COD is a measure of oxygen consumed by rigorous chemical oxidation of all reduced compounds present. True colour is measured on a filtered sample and the higher the number, the more intense the colour. Odour is expressed as threshold number, which is the greatest dilution with odour-free water that just allows perceptible odour. Both colour and odour are normally high in kraft pulping wastewaters. Lignin is one of the main components of wood. It is dissolved out of the wood pulp in the mill and is elevated in the wastewaters. Phenolic compounds are elevated in many wastewaters and are of concern because of their toxicity and tainting potential. In addition to simple dilution and downstream transport, organic matter is subject to a number of fate processes in river systems including biochemical transformation, sorption and sedimentation, biological uptake, and volatilization.

Phenols

Phenols, i.e. compounds that react positively in the phenolic test, were about 100 times more concentrated in the pulp mill final effluent than in the background river samples (Tables 3, 4, and

5). As a result, downstream concentrations were elevated in March, September, and November (Figure 7). Loading calculations indicate the storm sewer/cooling water was an insignificant source of phenols, and that the load from the final effluent was on average about two thirds of the phenol load at Site W2 (Table 6). No effect was apparent in May when river flows were high, but on the other three occasions the increased concentration at W2 then decreased back to an intermediate level upon mixing with the Smoky River, and remained fairly constant down the Smoky until further dilution in the Peace River (Figure 7).

Tannin And Lignin

Lignin is the compound in wood primarily responsible for its rigidity, and is dissolved out of the wood by the kraft process. Tannin is also present in plant matter and reacts the same as lignin in the analytical test. Since the pulping process specifically extracts lignin from the wood, lignin is likely the main constituent detected in this study. Tannin and lignin were approximately 100 $mg \cdot L^{-1}$ in the mill's final effluent whereas background river values did not exceed 1 $mg \cdot L^{-1}$. Input from the final effluent increased concentrations downstream in March, September, and November particularly at Site W2 (Figure 8). Downstream of there dilution with the Smoky River occurred although the pattern in the Smoky River varied between sampling occasions, sometimes declining downriver and other times remaining more constant (Figure 8). No effect was observed in May, when river flows were high.

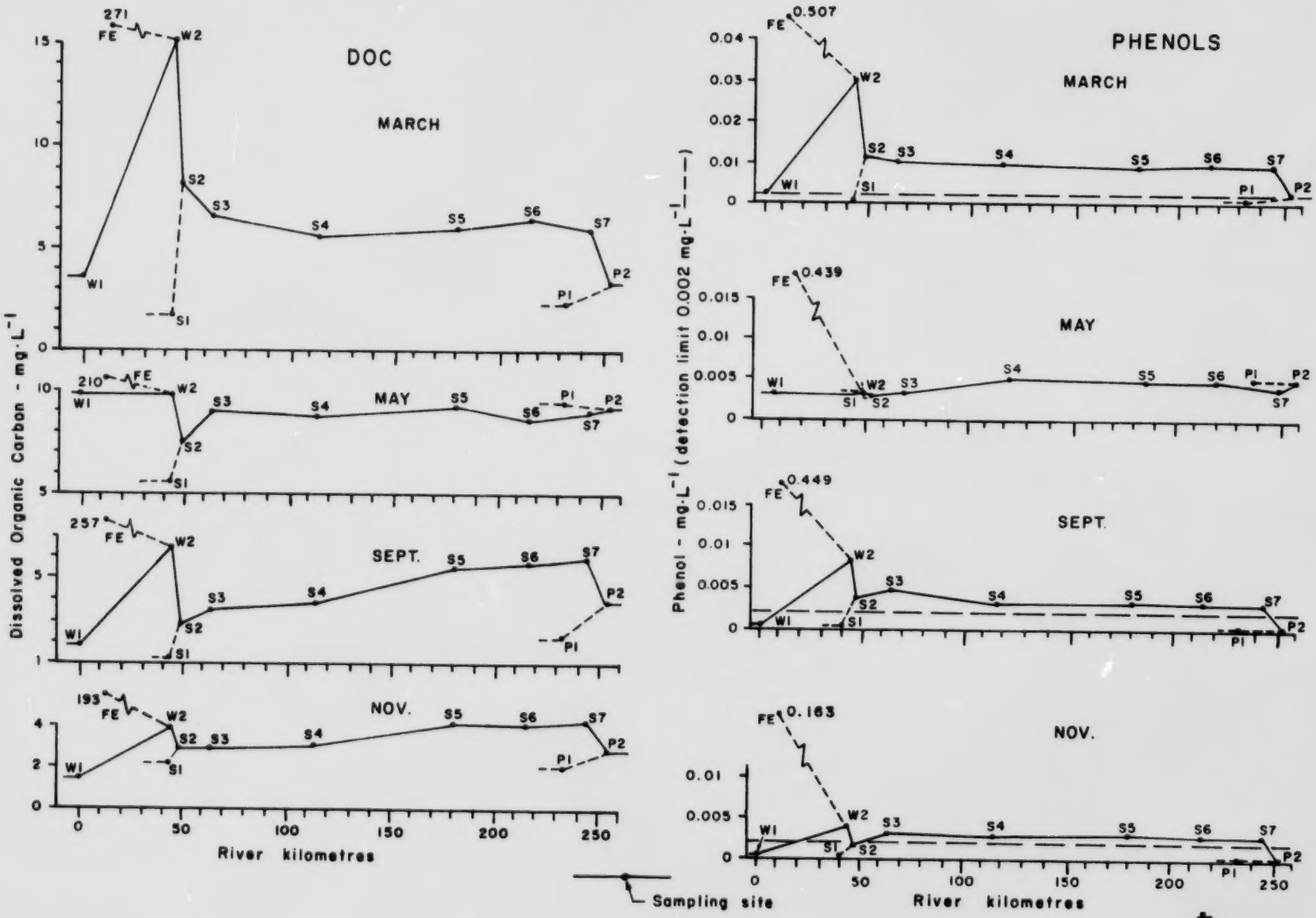

Figure 7. Dissolved Organic Carbon and Phenols concentrations, 1983.

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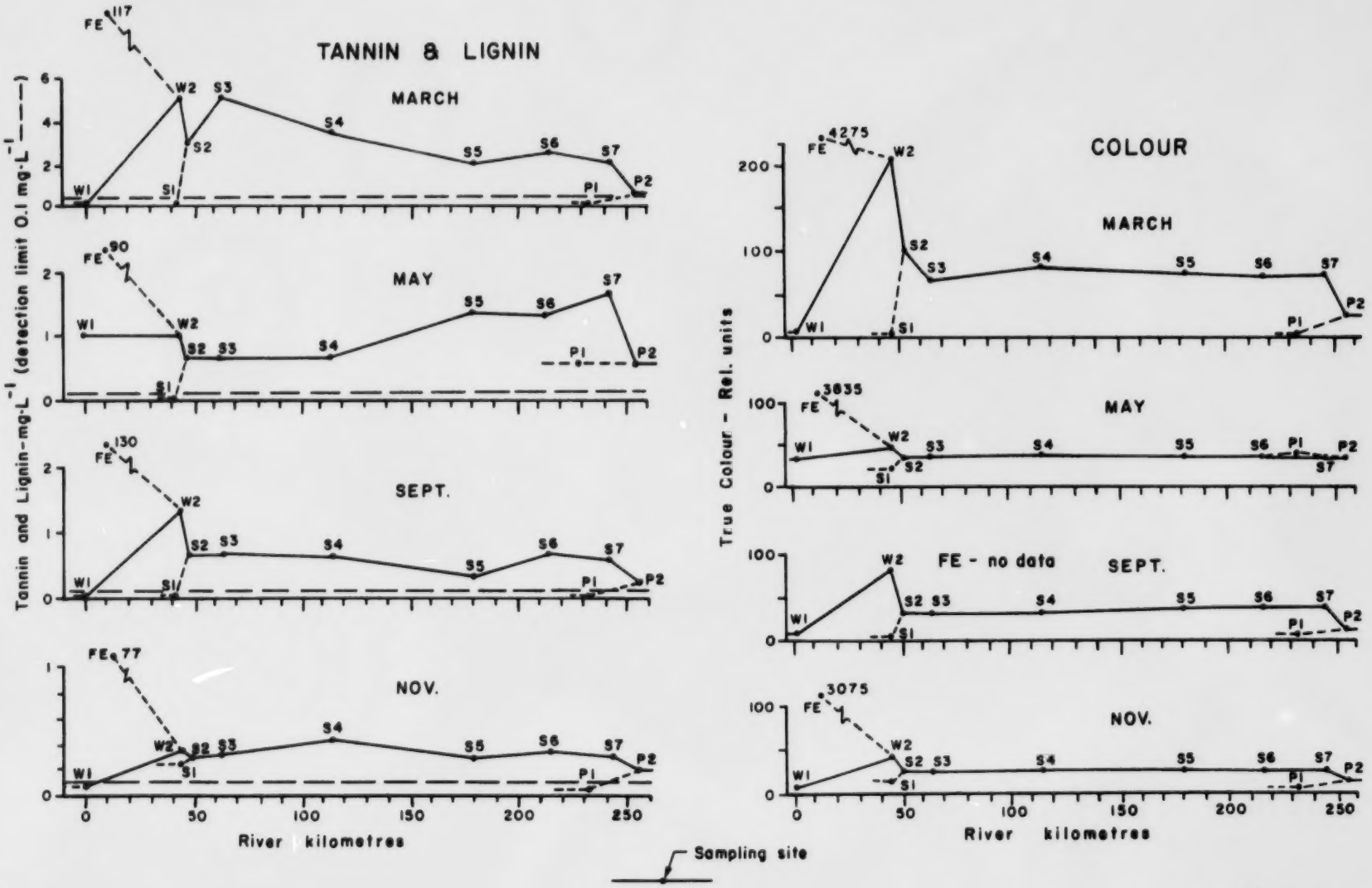

Figure 8. Tannin & Lignin and Colour concentrations, 1983.

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Colour (true)

True colour can be imparted by inorganic compounds such as iron and colloidal $CaCO_3$, and by dissolved organic matter such as humic acids, and tannin and lignin (Wetzel, 1983). In this case, the pulp mill final effluent was several hundred times more coloured than the upstream Wapiti or Smoky rivers (Tables 3, 4, 5). As a result, true colour was elevated downstream in the rivers (Figure 8), particularly so in March when river discharge and dilution were the least. The general pattern downstream was for a marked increase in colour at W2, then dilution to intermediate colour levels in the Smoky River at Sites S2 and S3, and then fairly constant colour downstream until dilution in the Peace River. The exception was in May when all the rivers had highest background colour, likely related to the high river discharge then. The general effect of the pulp mill effluent on colour in the Smoky River was to alter the timing of greatest colour: upstream in the Wapiti and Smoky (Sites W1 and S1) true colour was greatest during spring runoff in May, whereas downstream of the final effluent it was greatest during March when river dilution was least (Figure 8).

That the final effluent was the cause of colour increases downstream is indicated by mass balance calculation of the colour "load" (Table 7). Although colour is an optical or physical parameter, not a solute, it apparently behaves somewhat like a solute in that the total load (true colour units times volume of discharge per unit time) from the various upstream inputs balances reasonably well with the load at Site W2 downstream. Except during high flows in

TABLE 7 Colour "loads", 1983

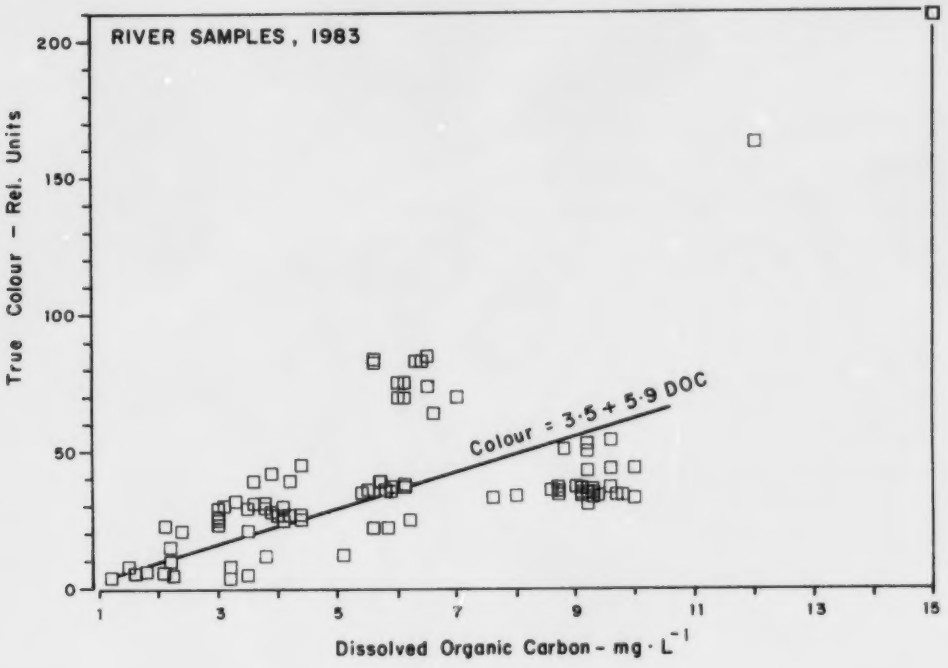
	Estimated "Load" - 10^3 True Colour Units•m^3•d^{-1}					Load Ratios		
	SITE							
	W1	SS/CW	FE	W2	S5	$\frac{W1+SS/CW+FE}{W2}$	$\frac{FE}{W2}$	$\frac{FE}{S5}$
March	4,200	0.014	214,000	177,000	259,000	1.24	1.21	0.83
May	638,000	0.023	208,000	826,000	1,670,000	1.02	0.25	0.12
November	38,400	0.011	171,000	202,000	440,000	1.04	0.85	0.39

No FE colour data available for September.
Flow at W2 taken as equal to flow at W1.

May, the final effluent accounts for much of the colour load at W2 and also at Site S5 on the Smoky River (Table 7). That colour can be mass-balanced in this way may indicate that most of the colour is imparted by one main solute and is proportional to the concentration of that solute. Colour has been linked with tannin and lignin in the past and in this case the two were also correlated ($r^2 = 0.66$; $n = 93$; Figure 9). Other compounds may also contribute to colour, particularly organic compounds, but T&L are likely the main cause since colour was not as well correlated with DOC ($r^2 = 0.33$; $n = 97$; Figure 9).

Odour

Like colour, odour is a 'composite' sensory parameter, but is more subjective in measurement. In 1983, the pulp mill final effluent had elevated odour on three of the four sampling occasions but the storm sewer/cooling water was no different from background river samples (Table 3 and 4). The river water always had a just perceptible natural odour (threshold number of 1). Downstream of the pulp mill, measured odour exceeded background values in only one instance - at Site W2 in May (Appendix 6). All other sites and times had odour values of one. However, these should be taken as minimum odour values, since odour can dissipate during sample transit and lab handling. An odour of the water characteristic of pulp mills was actually detectable at sampling sites in some instances, even though the lab analysis reported odour similar to background. This illustrates the limitations of the odour test.



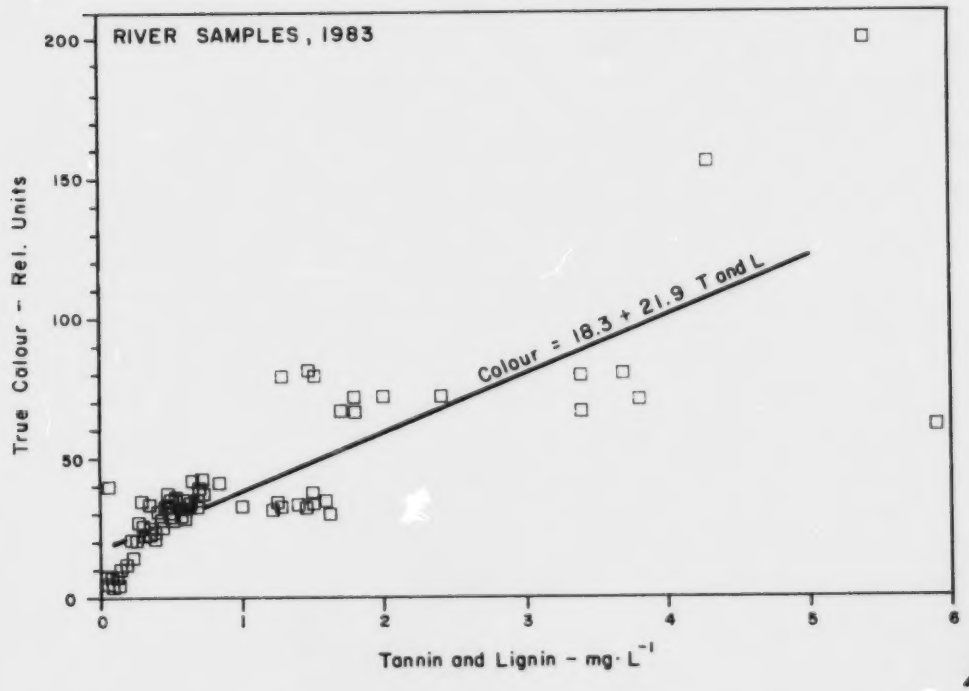


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Figure 9. Colour versus DOC and tannin and lignin in river samples.

Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD)

The BOD measurement reported here is the loss of oxygen in a sample incubated for 5 days at 20°C in the dark. It is a measure of the oxygen demand that wastewaters may place on receiving waters. The BOD of the final effluent was 31-70 $mg \cdot L^{-1}$, and that of the storm sewer/cooling water was <1-8 $mg \cdot L^{-1}$. Background river samples did not exceed 1.6 $mg \cdot L^{-1}$. River BOD was highest at all sites during May, likely as a result of high flows carrying suspended organic material. Downstream of the effluents some increase in BOD occurred at site W2 (up to 3 $mg \cdot L^{-1}$) but no increase in BOD was observed beyond that site (Appendix 6). Note that BOD itself may decline as organic compounds in the water are degraded or settle out. Despite the moderate increase in BOD at W2, dissolved oxygen there and farther downstream at S5 remained at 9.5 $mg \cdot L^{-1}$ or more during the ice-covered period in this study (Section 3.2.4.2).

Mass balance calculations for May samples indicate that BOD 'loads' were as follows:

Site:	W1	SS/CW	FE	W2	S5
Load ($kg \cdot d^{-1}$):	30,000	7	3,000	51,000	89,000

This shows the relatively small contribution of the final effluent to the river load (6%) during high flows. Although the calculated load of W1 + SS/CW + FE only accounts for about 66% of the load measured at site W2, there is considerable measurement error involved since the river BOD was near the detection limit. In March and September, the

final effluent load was 174% and 81% respectively, of the BOD load at W2:

	FE	W2
March	3300 $kg \cdot d^{-1}$	1900 $kg \cdot d^{-1}$
September	2500 $kg \cdot d^{-1}$	3100 $kg \cdot d^{-1}$

this illustrates the potential importance of the mill effluent in the river's organic load and oxygen demand during lower flows.

The COD parameter is a measure of the oxygen consumed in the chemical oxidization of all reduced compounds present, including organics, nitrites, sulfides, ammonia, etc. and will always be greater than BOD in a given sample. This was the case during the study and COD values showed a similar pattern to those of BOD (Appendix 6).

Dissolved Organic Carbon

This parameter is a measure of the carbon content of dissolved organic matter and can include both natural and anthropogenic compounds. At the upstream sites in the Wapiti, Smoky, and Peace rivers DOC ranged from about 1 to 10 $mg \cdot L^{-1}$ with highest concentrations in May (Figure 6), likely as a result of high flows carrying in organic-rich water from overland runoff. The pulp mill final effluent was about two orders of magnitude higher in concentration than the rivers while the storm sewer/cooling water was similar to the rivers in the concentration of DOC (Tables 3 and 4). The mill effluent caused increases in DOC downstream in the rivers on 3 of the 4 occasions, the amount of increase being greatest during March low flows (Figure 6) and at site W2. Mixing with the Smoky

River then lowered DOC concentrations, but downstream in that river there was a tendency for concentrations to rise slightly, perhaps as a result of tributary inflow. Mixing with the Peace River usually lowered concentrations again (Figure 6).

3.2.4.3.2 Trace Organic Compounds

This group will be defined as those analyzed by gas chromatography-mass spectrometry (GC-MS), but excluding pesticides. The analysis was for trace organic, non-pesticide 'priority pollutants' (Appendix 10), which are the organic contaminants of highest priority in aquatic systems, identified by the US Environmental Protection Agency (USEPA 1986; Keith and Telliard, 1979). In addition 'non target' organic compounds were detected and their concentrations estimated (Appendix 7). Trace organic results are summarized in Table 8, which for brevity, only includes detected compounds. Even though a priority pollutant may be absent from Table 8, it was analyzed nonetheless (Appendix 10), but not detected.

The dimethyl sulphides were present in the final effluent in variable concentrations, up to about 1000 $\mu g \cdot L^{-1}$ (Table 8). Dimethyl disulphide was usually predominant. These and other organic sulphur compounds are often associated with the odour of pulp mill effluents. They were not detected in the river samples, despite the fact that some odour was present at the sampling sites (Section 3.2.4.2.1 - Odour). It is possible they were present but at levels less than the detection limit (25 $\mu g \cdot L^{-1}$).

TABLE 8 Summarized trace organic findings, 1983

Parameter	Month:	March					May				
	Site:	P&GFE		W2	S5L	S5R	P&GFE		W2	S5	P2
	Day:	15	16	15	15	15	10	11	10	11	12
Sulphides											
dimethyl sulphide		25-50	25-50				75-100	25-50			
dimethyl disulphide		125-150	150-200				250-300	75-100			
dimethyl trisulphide		75-100	250-300				100-150	25-50			
[1]Organic Priority Pollutants											
[2]trichlorophenols		5-10	1-5				1-5	1-5			
[2]tetrachlorophenols		5-10									
carbon tetrachloride				tr	tr						
chlorobenzene				tr		3.7					
chloroform		40	48	5.8	4.1	3.6	43	37	0.2		
1,1-dichloroethylene					tr						
trans-1,2-dichloroethylene											
tetrachloroethylene											
[methylene chloride]						5.6			12	3.6	
toluene				0.1							
trichlorofluoromethane									tr	tr	tr
[di-n-butylphthalate]											
[bis(2-ethylhexyl) phthalate]											
[1]Other trace organic compounds		320	1,600	0.1	1.2	0	1,015	400	0.1	0	0
Total (rounded)		630	2,100	6	5	13	1,500	600	13	4	0.3

Parameter	Month:	September					November				
	Site:	P&GFE		W2	S5	P2	P&GFE		W2	S5	P2
	Day:	27	28	27	28	29	2	3	2	2	3
Sulphides											
dimethyl sulphide		150-200	50-100				50-100	100-200			
dimethyl disulphide		750-1000	750-1000				200-375	300-400			
dimethyl trisulphide		250-300	200-350					50-100			
[1]Organic Priority Pollutants											
[2]trichlorophenols		tr	2.0				NA	tr			
carbon tetrachloride											
chlorobenzene											
chloroform		110	109	0.9			139	183	1.2		
1,1-dichloroethylene											
trans-1,2-dichloroethylene		47	44				17				
tetrachloroethylene			0.2				0.2	0.2			
[methylene chloride]											
toluene		3.2	4.2				0.7	0.8			
trichlorofluoromethane			8.0								
[di-n-butylphthalate]			tr	tr			NA				
[bis(2-ethylhexy) phthalate]			tr	tr			NA	tr	tr	tr	tr
[1]Other trace organic compounds		490	360	0	75	0	NA	140	0.1	0	0
Total (rounded)		2000	1700	1.5	76	0	-	900	1.4	0.8	0.8

Values are $\mu g \cdot L^{-1}$. P&GFE = Procter and Gamble final effluent. L = left downstream. R = right downstream. Other river sites were cross channel composites. NA = not analyzed. Blanks indicate not detected: quantification limits are 1 $\mu g \cdot L^{-1}$ for all except sulphides (25$\mu g \cdot L^{-1}$) and volatiles (0.1 $\mu g \cdot L^{-1}$). tr = trace less than quantification limit. Totals are calculated from mid-range values. Brackets indicate tentative presence.

[1] See Appendices 7 and 10 for all parameters analyzed.

[2] All isomers

The 'priority pollutants' detected in the samples were mostly chlorinated organics, of which chloroform was detected most often and in the highest concentrations (Table 8). Chloroform was in the 40-180 $\mu g \cdot L^{-1}$ range in the final effluent, similar to findings in 1981-82 by the Alberta Environmental Centre (1987). River concentrations were highest in March, up to 5.8 $\mu g \cdot L^{-1}$, when river flow and dilution was lowest. Quite likely the March ice cover prevented evaporation of the chloroform, since chloroform persisted downstream to at least site S5. On the other sampling occasions chloroform was not detectable downstream of Site W2, likely as a result of dilution and evaporation. That the final effluent was the source of the chloroform is indicated by the following loads of chloroform (as $kg \cdot d^{-1}$):

Site	March	May	September	November	Mean
FE	2.2	2.3	6.4	8.7	4.9
W2	5.0	4.0	2.9	5.7	4.4

Individual sampling dates show discrepancies in load between these two sites, likely due to short-term variations in concentration and discharge, sampling and analytical error, and loss in the river. However, averaged over the four dates, the two loads are fairly similar.

Other organic priority pollutants detected in the final effluent include trichlorophenols, chloroethylenes, toluene, and trichlorofluoro-methane (Table 8). The chlorinated organics are likely by-products of the pulp mill's bleaching process, which uses chlorine compounds. Such compounds are commonly found in this type of

effluent (McLeay 1987; Cherwinsky and Murray 1986; Leuenberger et al. 1985). Most of these compounds are somewhat volatile and likely evaporate from the river. Of this group only toluene was detected in river samples, and only on one occasion, at 0.1 $\mu g \cdot L^{-1}$ (Table 8).

Some additional priority pollutants were detected in the river samples but not in the final effluent. Phthalates were detected at trace levels (Table 8), but such detections often occur, even in apparently uncontaminated surface water samples (Alberta Environment, unpublished data). They may result from contamination during sampling or analysis since phthalates occur in plastics, which are common in field and lab equipment. The detections in this case can not be taken as 'real' without further investigation. In March and May, carbon tetrachloride, chlorobenzene, and methylene chloride were also detected in the river but not in final effluent samples. These chlorinated organics could be originating from the pulp mill's chlorine bleaching, but if so, should have been detected in effluent samples. The reason for this discrepancy is not known. Methylene chloride is a common lab reagent in organic analysis and its detection here also can not be taken as 'real' without further investigation.

Numerous other organic compounds were identified in the samples by the GC-MS analysis, including phenolics, alkyldienes, ketones, alcohols, and aromatics (Appendix 7). Sulphones (organic sulphur compounds) were present in all effluent samples. The total concentration of these trace organics generally did not exceed about 1.6 $mg \cdot L^{-1}$. Most of them were not detected in the river samples, likely because they were diluted to less than detectable

concentrations (Appendix 7). However, additional compounds were undoubtedly present but were not amenable to GC-MS analysis at the time. Examples are resin and fatty acids, which are common in pulp mill effluents (Cherwinsky and Murray, 1986; D. McLeay and Associates 1987) and which have been detected subsequently in the Procter and Gamble final effluent (Alberta Environment unpublished data).

3.2.4.3.3 Total Organic Compounds

The organic constituents analyzed in this study are summarized in Table 9 for selected sampling sites. Total dissolved organic compounds are estimated by expressing DOC as an equivalent total organic weight, assuming it to have a stochiometry of C:2H:O (carbohydrate). The data indicate that phenolics, trace organics, and tannin and lignin accounted for about 3-18% of the total organics present, with the highest percentage being in the final effluent. The identity of the remaining organic constituents is not known but they could include proteins, carbohydrates, fats, resin acids and, especially in the river samples, humic and fulvic acids (Wetzel 1983; McLeay and Associates 1986).

3.2.4.4 Nutrients

Included in this group are the plant 'macro'-nutrients nitrogen (N) and phosphorus (P), which are the two nutrients most often limiting the growth of aquatic algae and macrophytes.

Nitrogen - NO_2, NO_2+NO_3, NH_3, total Kjeldahl nitrogen (TKN)

The various forms of nitrogen listed above are linked in the aquatic nitrogen cycle through the processes of ammonification,

TABLE 9 Summary of organic compounds, 1983

Site:	W1 and S1	FE	W2	S5	P2
Parameter					
Phenolics	0.002	0.309	0.011	0.005	0.003
Tannin & Lignin	0.3	104	2.1	0.9	0.4
Trace Organics	NA	1.2	0.005	0.022	0.0004
Total	(0.302)	105.5	2.1	0.9	0.4
DOC, as CH_2O	8.5	582	21	16	12

Results as mg/L. NA = not analyzed. Data are means of the four sampling occasions. W1 and S1 were similar and are averaged together.

nitrification, and de-nitrification. Nitrite (NO_2^-) is an intermediate, partly oxidized ion which is usually scarce in surface waters since it rapidly oxidizes to the more stable nitrate (NO_3^-). Nitrite was apparently the predominant ion of the two in the final effluent, but was not detected in river samples (Appendix 6). The two forms combined (NO_2+NO_3-N) were not markedly higher in the final effluent than in background river samples (Table 5).

Ammonia nitrogen (NH_3-N) includes both free ammonia (NH_3) and the ammonium ion (NH_4^+) since both are detected by the analytical method. In surface waters the two are in a dynamic equilibrium controlled primarily by temperature and pH. Free ammonia is the form which is toxic to aquatic life and the proportion of free ammonia increases with increases in temperature and pH (CCREM, 1987). Background NH_3-N levels in the Wapiti and Smoky ranged from 0.005 to 0.120 $mg \cdot L^{-1}$ (Table 3) and although the range in the final effluent was only slightly higher (0.016-0.185 $mg \cdot L^{-1}$: Table 4), on any given date NH_3-N in the effluent was from 2 to 15 times greater than in the river. Downstream concentrations appeared to be elevated on 3 of the 4 sampling occasions (Figure 10), although the downstream increases did not always correspond well to the apparent effluent input. For example, in March NH_3-N at Site W2 was actually higher than the two-day average final effluent concentration. Such discrepancies may reflect fluctuations in effluent quality (NH_3-N was quite variable from day to day - Appendix 6) as well as in-stream ammonification, volatilization, and nitrification, and tributary inputs. The

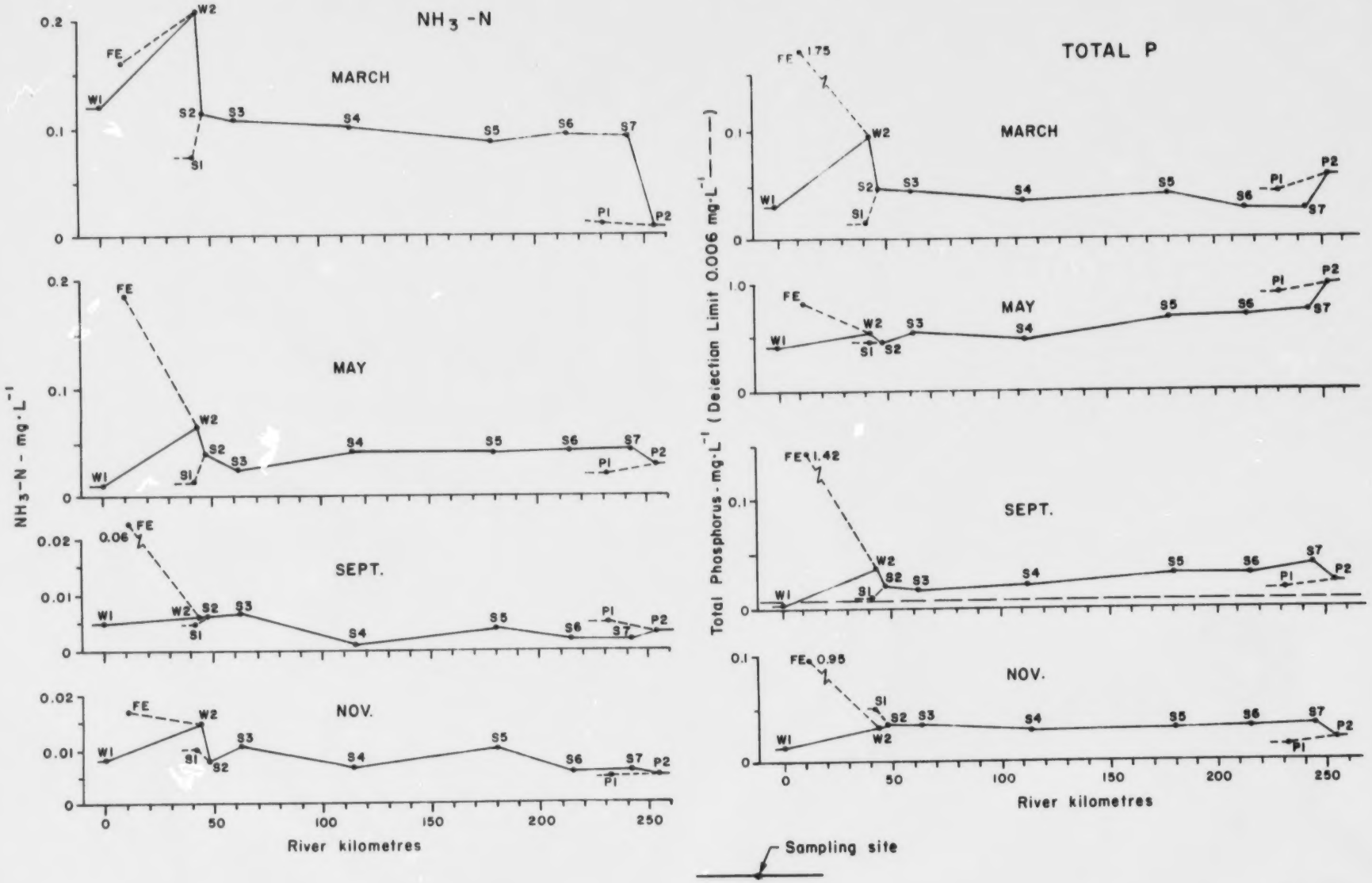

Figure 10. Ammonia and phosphorus concentrations, 1983.

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Grande Prairie sewage lagoon was much higher in NH_3-N (Appendix 8) and discharge of this lagoon down the Bear River in spring and fall may have influenced river concentrations.

As with many of the other parameters affected by the mill effluent, the downstream pattern in NH_3-N was an increase at Site W2, a decrease at S2 as a result of dilution with the Smoky River, fairly constant concentrations down the Smoky, and then a decrease (on 3 of 4 occasions) with dilution in the Peace River (Figure 10). The NH_3-N levels in the Wapiti and Smoky were highest in March, at about 0.1 $mg \cdot L^{-1}$.

Total Kjeldahl nitrogen (TKN) includes NH_3-N and organic nitrogen in the analysis. As such it will be influenced by the total organic content of the water. Compared to background river concentration, the pulp mill's final effluent was about an order of magnitude higher in TKN (Tables 3 and 4), which reflects the effluent's enrichment in organic material and ammonia.

Phosphorus

Phosphorus is the single nutrient most often limiting aquatic plant growth, and in surface waters occurs in organic and inorganic compounds, and in dissolved and particulate forms. The total phosphorus determination (TP) used in this study quantifies all of these forms of phosphorus. The mill's final effluent contained a TP concentration that was about 10 times higher than the rivers at background sites (Tables 3 and 4). However, when calculated as an average load over the four sampling occasions, the mill effluent

accounted for only 3% of the estimated load at Site W2 (Table 6). This likely reflects the high flow and TP concentrations in the river in May which were essentially natural, and which overwhelmingly dominated the total load among the four dates. Little effect of the final effluent on river TP was discernible in May (Figure 10) although in March, September, and November it appeared to increase TP at Site W2. However, wastewaters from Grande Prairie entering via the Bear River may also have influenced TP at Site W2. Mixing with the Smoky River reduced the TP concentration on 3 occasions, then downstream in the Smoky little change in concentration was observed. Concentration in the Peace River varied, twice being higher, and twice lower than in the Smoky River. Overall, TP was highest in May, probably as a result of the high flow and high suspended solids (NFR) in the rivers then. Total phosphorus is often positively correlated with suspended solids in rivers and has been found to be so in the Smoky River at Watino (Blachford et al. 1985).

3.2.4.5 Metals

The members of this group which were analyzed in 1983 include Al, As, Be, Cd, Co, Cr^{+6}, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, V, and Zn. All of these elements can occur naturally in rivers, and their total concentrations are often positively correlated with the suspended solid content of the water such that they increase when river flow increases (Hem 1970; Allan, 1986). Industrial and municipal wastewaters can contain elevated concentrations of metals. In the case of the Procter and Gamble pulp mill, no mill process specifically uses metals or metal compounds, and most metals were not

notably elevated in the final effluent as compared to background river concentrations (Table 5). Although Cd, Cu, Fe and Pb were increased about 3 to 5 times in the final effluent, no effect on river concentrations occurred. Manganese and Zn were increased about an order of magnitude in the final effluent (Tables 3, 4, 5) and are discussed below. In the storm sewer/cooling water Mn and Zn concentrations were only notably high in May, at which time NFR was also very high (Table 4) and these two metals were likely associated with the particulate material. Aluminum was very high in the storm sewer in May (Table 4), likely as a result of aluminum hydroxide sludge discharge (allowed under licence). Background river concentrations of Al were also high then and no effect on downstream concentrations was apparent (Appendix 6).

Manganese (Mn)

The median concentration of Mn in the final effluent during the study was about 0.5 $mg \cdot L^{-1}$ and concentrations did not fluctuate markedly (Table 4). Background Mn concentrations in the rivers were lower and fluctuated between about 0.01 and 0.04 $mg \cdot L^{-1}$ except in May, when flow, NFR, and Mn were all higher (Table 3). The mill's final effluent caused distinct increases in Mn at Site W2 in March and September but not in May or November (Figure 11). Although Mn increased at W2 in May, there was a broader trend of increase down the Wapiti - Smoky river system then and the final effluent load (approximately 27 $kg \cdot d^{-1}$) could not account for the increase at W2 (approximately 680 $kg \cdot d^{-1}$ more than at W1). More likely,

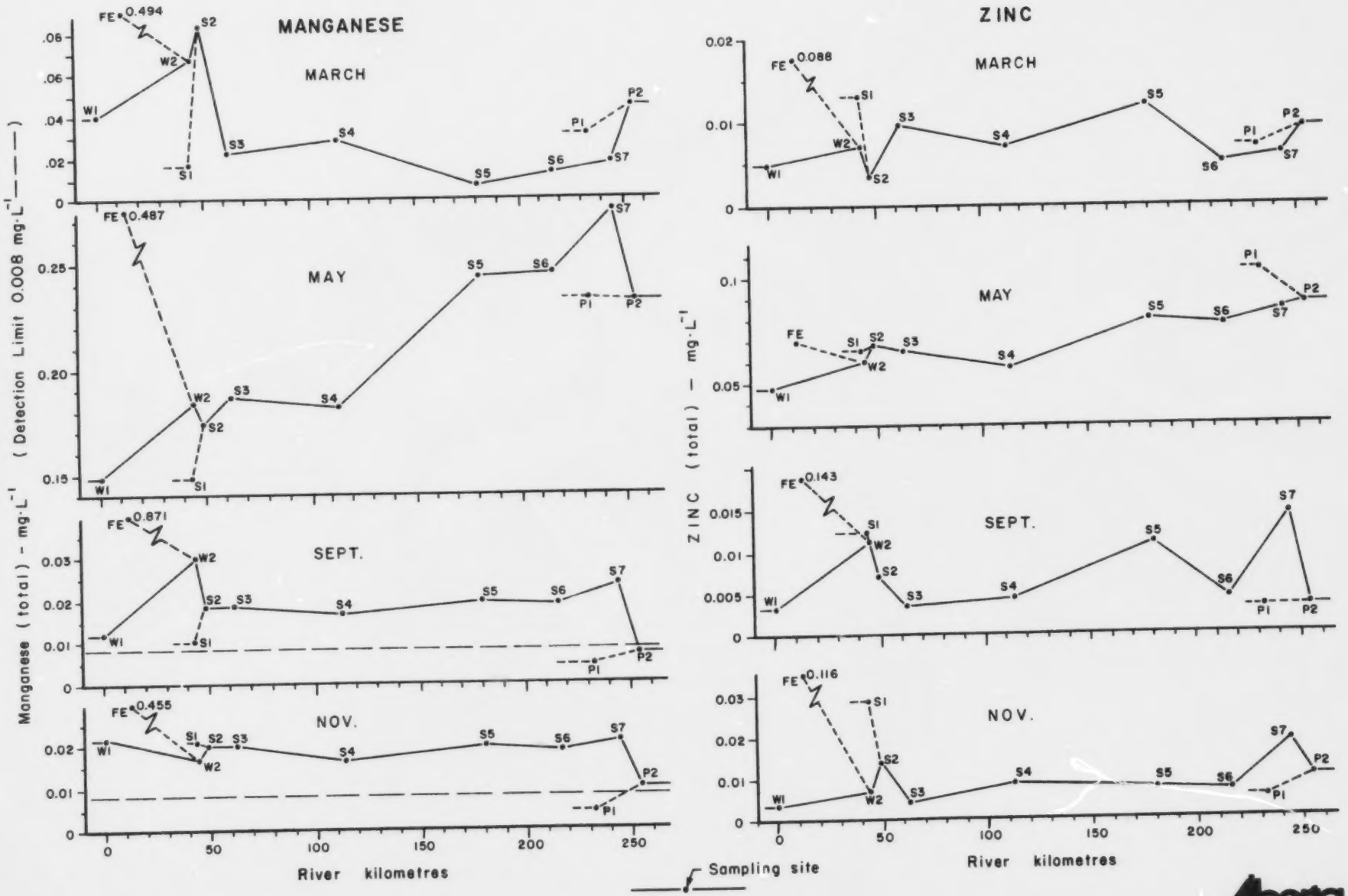

Figure 11. Manganese and Zinc Concentrations, 1983.

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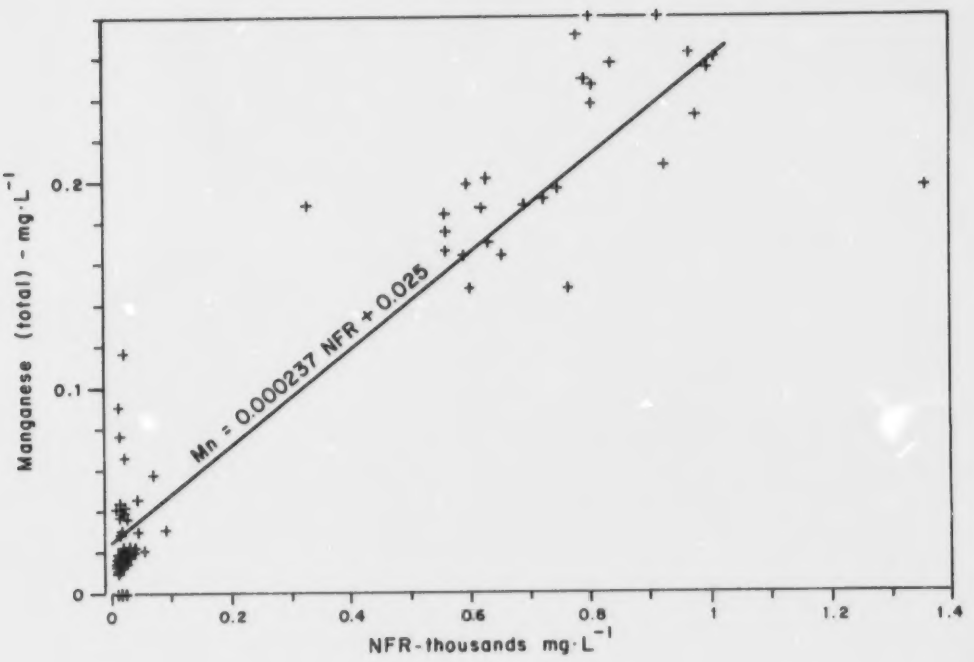
the Mn was associated with the naturally high suspended solids in the rivers during May high flows, since NFR also increased in concentration downstream (Figure 4). In fact, Mn concentrations were positively correlated with NFR in the river samples (r^2=0.90, n=92; Figure 12). Except at site W2, the concentration of NFR rather than the mill effluent appears to account for much of the concentration of Mn. The Peace River was lower in Mn than the Smoky on 3 of the 4 sampling occasions (Figure 11).

Zinc

Background river concentrations of total Zn ranged from 0.003 to 0.028 $mg \cdot L^{-1}$ except during May high flows, when they rose to 0.05 - 0.1 $mg \cdot L^{-1}$ (Table 3; Figure 11). Zinc concentrations in the pulp mill final effluent were about 10 times higher than in the rivers, except during May when there was little difference. On the other three occasions the effluents appeared to raise Zn concentrations at Site W2 as compared to W1. Downstream of there concentrations were quite variable. The upper Smoky River was higher in Zn than the Wapiti, consequently little effect of the mill effluent on Zn was observable in the Smoky River (Figure 11). As with Mn, total Zn concentrations were strongly correlated with NFR (r^2=0.92, n=97; Figure 12) indicating that the Zn is largely associated with suspended solids and that the concentration of the latter explains most of the variation in Zn concentrations in the Smoky River. Loading calculations also indicate the pulp mill wastewaters were a minor source of Zn in the Smoky (Table 6).



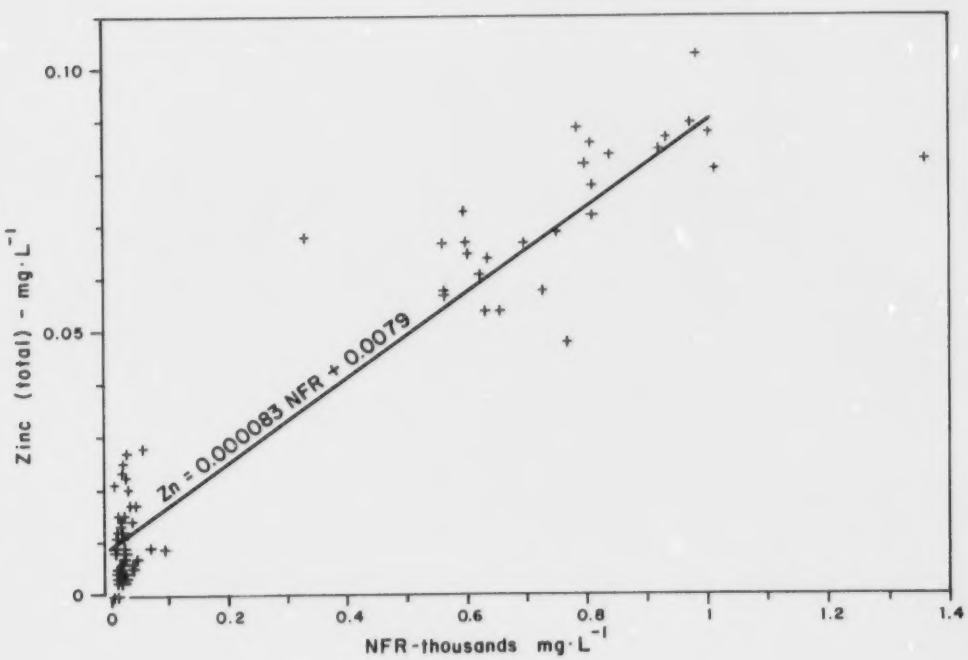


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Figure 12. Manganese and zinc versus non-filterable residue in river samples, 1983.

3.2.4.6 Bacteria

Bacteria are naturally occurring organisms and are mostly consumers of organic compounds and detritus. Numerous species of bacteria occur in surface waters and their densities are often correlated with the amount of organic material present. Such naturally occurring bacteria are generally not pathogenic to humans. Wastewaters which contain sewage or elevated amounts of organic material are likely to contain elevated densities of bacteria, and if human sewage is involved, waterborne pathogenic organisms (bacteria, viruses, protozoans) could be present. Bacterial analysis is often used to provide an indication of sewage or fecal contamination. In this project, bacterial analyses included a standard plate count for heterotrophic bacteria (SPC), total coliform (TC), fecal coliform (FC), and fecal streptococci (FS) tests (Appendix 11).

Standard Plate Count

This test is a comparatively non-selective measure of heterotrophic bacteria, which are those that consume organic material (Greenberg et al. 1985). The test will detect many naturally occurring species as well as species present in wastewaters, and it is not a strict indicator of pathogens. The density of bacteria detected by this test should be broadly correlated to the amount of organic matter present. This was generally the case on the three sampling occasions in this study, where the pulp mill's final effluent, which was high in DOC, contained 3-4 orders of magnitude more bacteria than did background river samples (Figure 13). Bacteria are characteristic

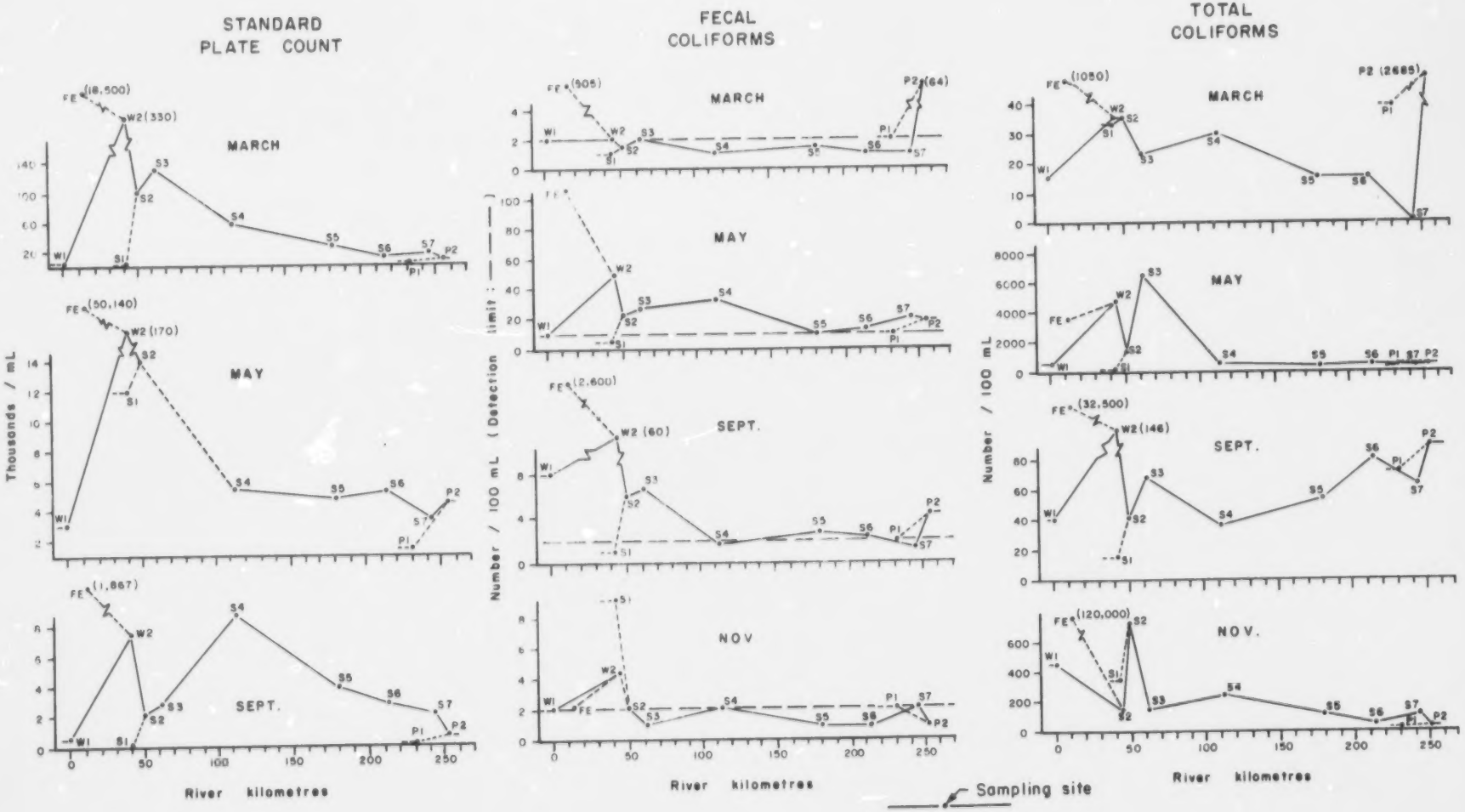

Figure 13. Bacterial densities, 1983

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of the wastewater treatment process and are the main agents of organic decomposition in the aerated lagoon. As a result of the effluent inflow bacterial densities were elevated at Site W2. Farther downstream, mixing with the Smoky River reduced densities, and in March and May densities declined further downstream. In September, they rose at Site S4, before declining down the river. The Peace River was lower in heterotrophic bacteria than the Smoky near their confluence.

The trend of a downstream decrease suggests that the heterotrophic bacteria which likely originated in the aerated biological lagoon, are comparatively inactive once they enter the river and/or undergo considerable removal from the water. This contrasts with DOC concentrations which showed either no decrease or a slight increase downstream (Figure 6).

Total Coliforms

Total coliform bacteria include several rod-shaped species that ferment lactose with gas formation at 35°C in standard laboratory tests (Greenberg et al. 1985). Such bacteria are heterotrophic and include those of fecal origin but also numerous naturally occurring species. As a result, the density of total coliforms may be related to the presence of sewage, organically enriched wastewaters, or simply natural organic material, and the test is not a good pollution indicator. Its main use now is as a check on treated drinking water although it can be used to compare with historic data to assess trends (Health and Welfare Canada 1983).

Total coliform densities in background river samples (sites W1 and S1) ranged from about 15 to 500/100 mL with highest densities in May and November (Figure 13). The high densities in May likely result from high flows with consequent input of organic matter and bacteria. The November data may reflect stimulation of decomposers by autumn leaf fall and/or suspension of organic material and bacteria by the pulse in river discharge that occurred prior to sampling (Figure 2). Total coliforms were considerably higher in the final effluent on 3 of the 4 sampling occasions, reflecting the organic richness and bacterial abundance in the treatment lagoons. The pattern of densities downstream varied considerably, but in general, densities seemed to be elevated at Sites W2, S2 and S3 and then declined (on 3 of 4 occasions) downstream in the Smoky River. The increases were likely a result of the mill effluent although other inflows (municipal wastewaters via the Bear River) may also have contributed.

Fecal Coliforms

Bacteria detected in the fecal coliform analysis are those of the total coliform group that respond under a warmer incubation temperature (44.5°C). The test is generally an indicator of fecal contamination from warm-blooded animals, however, some non-fecal bacteria can also react positively in the test, notably Klebsiella. This genus is known to occur and to be able to grow in organically rich water such as pulp and paper mill wastes (Poole et al. 1978; Health and Welfare Canada 1983).

Fecal coliforms were no more than 10/100 mL and usually less in background samples from the three rivers. Except in November, concentrations were about 100 times higher in the mill final effluent. The identity of these bacteria is not known but the mill's wastewater treatment system receives plant sanitary sewage, and as noted above, Klebsiella is known to occur in pulp mill wastes. Concentrations downstream in the rivers were quite variable but on 3 of the 4 occasions there was a general increase in fecal coliforms at Sites W2, and S2, and then a decrease to background around S5 (Figure 13). The increase may have resulted from the final effluent although input from Grande Prairie wastewaters via the Bear River may also have occurred. Concentrations of fecal coliforms in the lower Smoky River were similar to those in the Peace River.

Fecal Streptococci

This bacterial analysis tests for members of the genus Streptococcus, most but not all of which originate from the intestines of warm-blooded animals (Greenberg et al. 1985). The fecal streptococci test is usually used in conjunction with fecal coliforms and the ratio of the two can provide information on the source of fecal contamination. The test has several limitations, notably that if numbers are less than 100/100 mL, non-fecal species tend to pre-dominate and then the FC:FS ratio is of no use. Only in May did fecal streptococci approach 100/100 mL and at that time background river samples (W1, S1, P1) were similar to samples downstream of the wastewaters (Appendix 11), suggesting no influence of the wastewaters

on river densities of FS. This suggests that the streptococci were actually non-fecal in May and is consistent with the high flows and suspended solids in May bringing in non-effluent bacteria. Concentrations in the final effluent were highly variable, ranging from <10/100 mL to 3300/100 mL. Whether these are of fecal origin is not known.

3.2.4.7 Acute Toxicity

Acute toxicity is the toxicity of a material to organisms during short-term exposure. The measure of acute toxicity used here was lethality to rainbow trout in a 96-hour static, multiple concentration bioassay. A sample of final effluent was collected on 28 September and tested for lethality at the Alberta Environmental Centre. There was no mortality of fish in the test, even in undiluted effluent, and thus the sample was not acutely lethal. Procter and Gamble also tested their final effluent for lethality using the same procedures on five occasions in 1983 (reports to the Pollution Control Division under Licences to Operate). On four occasions there was no acute lethality and on one occasion in May the LC_{50} was 95% by volume (the concentration of effluent that was lethal to 50% of the fish in 96 hours). This toxicity test is used as a general check on effluent quality, the goal being that the final treated effluent should not be acutely lethal.

3.2.5 Compliance

3.2.5.1 General

Water quality of the pulp mill wastewaters can be compared to the quality standards specified in the mill's Licence to Operate

under the Clean Water Act. River quality can be compared to the Alberta Surface Water Quality Objectives (Alberta Environment 1977), and to quality criteria or guidelines published elsewhere. However, the only quality standard or objective specific to the receiving rivers in this situation was an objective specified in the mill's Licence to Operate, for dissolved oxygen in the Wapiti River downstream of the mill.

3.2.5.2 Licence Limits

Licence limits are summarized in Table 10 along with the compliance measured in this study. Final effluent limits for BOD, COD, suspended solids, and odour were licensed on the basis of 24 hour composite samples and therefore, only composite samples for these parameters (from Appendix 6) were included in Table 10.

Measurements of most parameters complied with licence limits (Table 10). An exception was COD in the storm sewer/cooling water effluent where 2 grab samples in May (at 306 and 238 $mg \cdot L^{-1}$) exceeded the limit of 100 $mg \cdot L^{-1}$. Suspended solids were high in this effluent in May (Table 4) which likely accounts for the high COD. Background COD in the receiving rivers was also highest in May (Table 3). Some downstream increase in COD appeared at Site W2, (Appendix 6) but it was more likely attributable to the final effluent than to the storm sewer.

The only other parameter indicated to be non-compliant by samples collected in this study was total suspended solids (termed non-filterable residue here). One sample from each of the final effluent and the storm sewer/cooling water effluent appeared to exceed

TABLE 10 Compliance with licence conditions during sampling occasions in this study

Parameter	Licence Limit	No. of Samples	Number Complying
Final effluent			
BOD	10,200 $kg \cdot d^{-1}$ (if Wapiti flow >8.5 $m^3 \cdot s^{-1}$) 8440 $kg \cdot d^{-1}$ (if Wapiti flow <8.5 $m^3 \cdot s^{-1}$)	3	3
COD[2]	268,000 $kg \cdot d^{-1}$	2	2
Total Suspended Solids	12,500 $kg \cdot d^{-1}$	3	(2)[4]
Odour (thresh.no.)	1,000	3	3
pH(grab sample)	6.5-9.5	8	8
Toxicity (grab)	96 hr. LC_{50} Rainbow Trout - non toxic	1	1
Storm Sewer (grab)			
COD	100 $mg \cdot L^{-1}$	8	6
Total Suspended Solids[3]	50 $mg \cdot L^{-1}$	7	(6)[4]
pH[3]	6.5-9.5	8	8
Wapiti River, downstream			
Oxygen (grab)	$\geq$ 5 $mg \cdot L^{-1}$	1	1

[1] Clean Water Act, Licence to Operate #78-WL-078 (to 13 Oct 83), and #83-WL-096 (from 13 Oct 83). Based on 24 hour composite samples unless noted.

[2] Removed after 13 Oct 83.

[3] Except if high turbidity in Wapiti River upstream and if alum sludge (only) is being discharged into storm sewer (occurred in May).

[4] See text discussion.

the licence limits in September (Table 10, Appendices 6 and 12). However, the analysis for total suspended solids (NFR) carried out here used finer filters (0.45 µm) than was required by the Licence to Operate, and this may have increased the amount of suspended solids detected. Analyses reported by Procter and Gamble (to Alberta Environment) showed almost 100% compliance for suspended solids in 1983.

Procter and Gamble Cellulose Ltd. also reported analyses and loadings of the licence parameters to the Pollution Control Division, as required by their Licences to Operate. These reports are similar in findings to those in Table 10, i.e. that most parameters complied with licence limits in 1983. Exceptions reported by the company on the final effluent were for odour (2 out of 14 did not comply), toxicity (1 out of 5), and on the storm sewer, COD (1 out of 12).

3.2.5.3. Alberta Surface Water Quality Objectives (ASWQO)

Alberta Environment (1977) has established water quality objectives which are intended to protect the most sensitive water use. These objectives are province-wide although it is recognized that some natural surface waters may not meet them for all parameters, and individual water bodies must be assessed case-by-case. The ASWQO also recognize that quality criteria and guidelines are continually being refined and are also being developed for additional parameters.

Compliance of river quality with the ASWQO in this study is indicated at selected sites in Table 11. All samples collected at a site are considered (Appendix 6), as opposed to averaging left, right, and centre grabs. Bear in mind that the timing of sampling affects

TABLE 11 Compliance with Alberta Surface Water Quality Objectives in 1983

Parameter	ASWQO	Wapiti River		Smoky River			Peace River	
		W1	W2	S1	S3	S5	P1	P2
Oxygen	5	-	1/1	1/1	2/2	2/2	1/1	2/2
pH (units)	6.5-8.5	4/4	9/9	4/4	10/10	10/10	4/4	12/12
F	1.5	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Suspended Solids	+10	----------		See Text			----------	
Phenolics*	0.005	4/4	6/9	4/4	7/10	8/10	4/4	12/12
Odour (thr.no.)	8 (see text)	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Colour*	+30	----------		See Text			----------	
N, total*	1	3/4	6/9	4/4	7/10	7/10	3/4	8/12
P, total*	0.05	3/4	5/9	2/4	7/10	7/10	3/4	7/12
As	0.001	2/2	5/5	2/2	5/5	5/5	2/2	6/6
Cd	0.001	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Cr*	0.05	4/4	8/9	4/4	10/10	10/10	4/4	12/12
Cu*	0.02	4/4	6/8	2/4	8/10	8/10	3/4	8/12
Fe*	0.3	3/4	6/9	2/4	4/10	2/10	2/4	4/12
Hg (µg/L)*	0.1	3/4	9/9	4/4	7/7	10/10	4/4	12/12
Mn*	0.05	3/4	5/9	3/4	7/10	7/10	3/4	7/12
Pb	0.05	3/3	8/8	3/3	8/8	5/5	4/4	12/12
Se	0.01	3/3	5/5	2/2	5/5	5/5	2/2	6/6
Zn*	0.05	4/4	6/9	3/4	7/10	7/10	3/4	8/12
Fecal coliforms	----------			See Text			----------	
Total coliforms*	----------			See Text			----------	

ASWQO as maximum $mg \cdot L^{-1}$, unless noted. Metals as totals.
+ indicates maximum deviation from background value.
Compliance as number complying over number of samples.
* non-compliance observed.

the degree of compliance: taking the samples during low flow periods could show a different compliance than if samples were taken evenly during the year.

Eleven of the parameters complied in all samples collected whereas 10 showed some non-compliance. Oxygen was only measured on one occasion here, but monthly measurements at the Watino network site (equivalent to S5) were all above 5 $mg \cdot L^{-1}$ in 1983 (Appendix 9).

The objective for suspended solids (equivalent to NFR) is a maximum increase of 10 $mg \cdot L^{-1}$ over background values. On the four sampling occasions, the site downstream of the mill (W2) was no more than 10 $mg \cdot L^{-1}$ higher in NFR than the site upstream (W1 - Figure 4). The objective for colour is a maximum increase of 30 units over background. This was exceeded on all four samplings in the Wapiti River, based on the sites upstream and downstream of the pulp mill (Figure 6). It was exceeded on one of the four samplings in the Smoky River (March), based on the sites upstream and downstream of the Wapiti River inflow. This exceedance occurred during the lowest flows and is most likely attributable to colour input to the Wapiti from the pulp mill final effluent (see loading estimates, Table 7). Odour is shown to be in compliance but it was difficult to analyze and its compliance remains uncertain.

Phenolics complied with the ASWQO at background river sites but not always at sites downstream of the mill (Table 11). Compliance was poorest when flows were low (March and September) and much of the non-compliance is probably attributable to the pulp mill effluent (Figure 6, Section 3.2.4.3.1). Total nitrogen (total kjeldahl + NO_2

+ NO_3 nitrogen) exceeded the ASWQO in the May samples, even at background sites (W1 and P1) and the non-compliance appears to be natural. Total phosphorus was also non-compliant in May, likely as a result of high streamflow, high NFR, and high particulate P at background and other sampling sites. On the other sampling occasions, only site W2 in March did not comply with the ASWQO for phosphorus, likely as a result of the mill effluent (Figure 10).

Of the metals, Cr, Cu, Fe, Hg, Mn, and Zn were non-compliant at times (Table 11), mostly in May when flows and NFR were high. Such high concentrations and non-compliance appears to be due to the naturally high concentrations of NFR. The exception to this was Mn in March when the pulp mill effluent appeared to increase Mn concentrations above the ASWQO of 0.05 $mg \cdot L^{-1}$ at sites W2 and S2 (Figure 11).

The ASWQO for bacteria are specific to the intended use, require a minimum of 5 samples in any 30 day period, and can be summarized as follows:

	For supply to potable treatment plants, or for non-contact recreation	For direct contact recreation or vegetable crop irrigation
Fecal coliforms:	<1000/100mL in 90% of samples	- geom. mean $\leq$ 200/100mL - 80% of samples $\leq$ 200/100mL
Total coliforms:	<5000/100mL in 90% of samples	- geom. mean $\leq$ 1000/100mL - 80% of samples $\leq$1000/100mL - on any day $\leq$2400/100mL

Vegetable crop irrigation and contact recreation are not extensive along the Wapiti and Smoky rivers but may occur in perhaps

the May to early September period. The samples collected in this period for total coliforms (May - Appendix 11) did not comply with the objective for this use in the lower Wapiti and at Sites S2 and S3 in the Smoky River. All samples complied with the fecal coliform objective.

For potable supply and non-contact recreation, all Smoky River samples were examined, and found to comply with the fecal coliform objective. They also complied with the total coliform objective in March, September, and November, but not in May. The non-compliance in May for both uses may be partly attributable to the mill effluent but other factors could also be involved (Section 3.2.4.6).

3.2.5.4 Other Limits

The Canadian Council of Resource and Environment Ministers (1987) have recently published the Canadian Water Quality Guidelines (CWQG). The guidelines are water quality limits or statements recommended to support and maintain designated water uses. They are not site-specific but are intended to be used as information in establishing site-specific quality objectives. The parameters sampled in this study which were not included in the ASWQO were compared to the CWQG and their compliance tabulated in Table 12. Again, note that the degree of compliance may be affected by sample timing.

The guideline for NH_3-N varies with water temperature and pH. The limit was interpolated from temperature and pH of the samples collected, and all the NH_3-N concentrations (Appendix 6) complied with the CWQG. Except for Al, all other parameters also complied with

TABLE 12 Other parameters - 1983 river quality compared to Canadian Water Quality Guidelines

Parameter	CWQG $mg \cdot L^{-1}$	Wapiti River		Smoky River			Peace River	
		W1	W2	S1	S3	S5	P1	P2
Ca	1000	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Na	SAR<3	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Cl	100	4/4	9/9	4/4	10/10	10/10	4/4	12/12
SO_4	500	4/4	9/9	4/4	10/10	10/10	4/4	12/12
T. dissolved solids	500	4/4	9/9	4/4	10/10	10/10	4/4	12/12
NO_2-N	0.06	4/4	9/9	4/4	10/10	10/10	4/4	12/12
NO_2+NO_3-N	10	4/4	9/9	4/4	10/10	10/10	4/4	12/12
NH_3-N	See Text	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Al*	0.1	2/4	1/9	1/4	4/10	1/10	2/4	5/12
Be	0.1	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Co	0.05	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Mo	0.1	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Ni	0.065	4/4	9/9	4/4	10/10	10/10	4/4	12/12
V	0.1	4/4	9/9	4/4	10/10	10/10	4/4	12/12
Trichlorophenols	0.018	-	4/4	-	-	5/5	-	3/3
Tetrachlorophenols	0.001	-	4/4	-	-	5/5	-	3/3
Chlorobenzene	(0.015)	-	4/4	-	-	5/5	-	3/3
Tetrachloro-ethylene	(0.26)	-	4/4	-	-	5/5	-	3/3
Toluene	0.3	-	4/4	-	-	5/5	-	3/3
Trihalomethanes (incl. chloroform)	0.35	-	4/4	-	-	5/5	-	3/3

CWQG from Canadian Council of Resource and Environment Ministers (1987).
Limit is for most sensitive use, excluding industrial uses.
Compliance as number complying over number of samples. Blanks indicate no sample.
( ) indicates a tentative guideline.
* non compliance observed.

the CWQG. Aluminum often exceeded the limit of 0.1 $mg \cdot L^{-1}$ but the concentration of Al in the rivers appeared to be natural. Aluminum is one of the most abundant elements present in the earth's crust (McNeely et al. 1979), and its concentration increased in May when flows and NFR increased. Although Al was also high in the storm sewer/cooling water effluent from the pulp mill in May (perhaps due to alum sludge discharge), no effect on river concentrations were apparent then, or on the other sampling occasions (Appendix 6).

Of the remaining parameters sampled in this study which are not covered by the ASWQO or CWQG, two are addressed by the United States Environmental Protection Agency's "Quality Criteria for Water 1986." It summarizes the concentrations of various contaminants that have been observed to cause specific effects, such as acute or chronic toxicity. These are criteria (experimental data) as opposed to guidelines (a recommended limit) or objectives (an established goal). Carbon tetrachloride is the first parameter, and available data indicates acute toxicity occurs at concentrations of 35.2 $mg \cdot L^{-1}$ (USEPA 1986). No data are available on the chronic toxicity of this parameter. Of the three sites and four occasions sampled in this study, only on one occasion was a trace (<0.0001 $mg \cdot L^{-1}$) of carbon tetrachloride found (Table 8). Similarly, the USEPA acute toxicity criteria for dichloroethylenes is 11.6 $mg \cdot L^{-1}$, but only on one occasion was a trace (<0.0001/$mg \cdot L^{-1}$) of these compounds found (Table 8). These concentrations are substantially below the aquatic life criteria.

The USEPA criteria also address human health aspects. They state that for maximum health protection, considering exposure through ingestion of contaminated water and aquatic organisms, ambient water concentrations for these chemicals should be zero, based on the nonthreshold assumption. The document also notes that zero levels may not presently be attainable.

3.3 Algal Assays

Algal assays are laboratory incubations of a test algal species in a water sample. The assays carried out here used Selenastrum capricornutum Printz as the test species, and measured total growth of this species in the sample, normally termed algal growth potential (AGP). The AGP is a measure of the 'fertility' or nutrient status of the water.

Algal growth potential at the various sites is compiled in Appendix 13 and portrayed in Figure 14. It was quite variable and was about an order of magnitude higher in May than in September or November. There was no consistent effect of the pulp mill wastewaters on AGP: sites downstream of the mill had AGP values which were higher (September), lower (November) or no different (May) than sites upstream of the mill. The reason for such inconsistency is unknown, but is not surprising considering that what is being measured is only one species' growth. Small concentration changes in macro-nutrients (N and P), trace nutrients, and/or inhibitory compounds (e.g. phenolics) could easily cause the observed variation in results. Municipal wastewaters entering via the Bear River may also have affected the assays. There was a poor correlation between AGP and

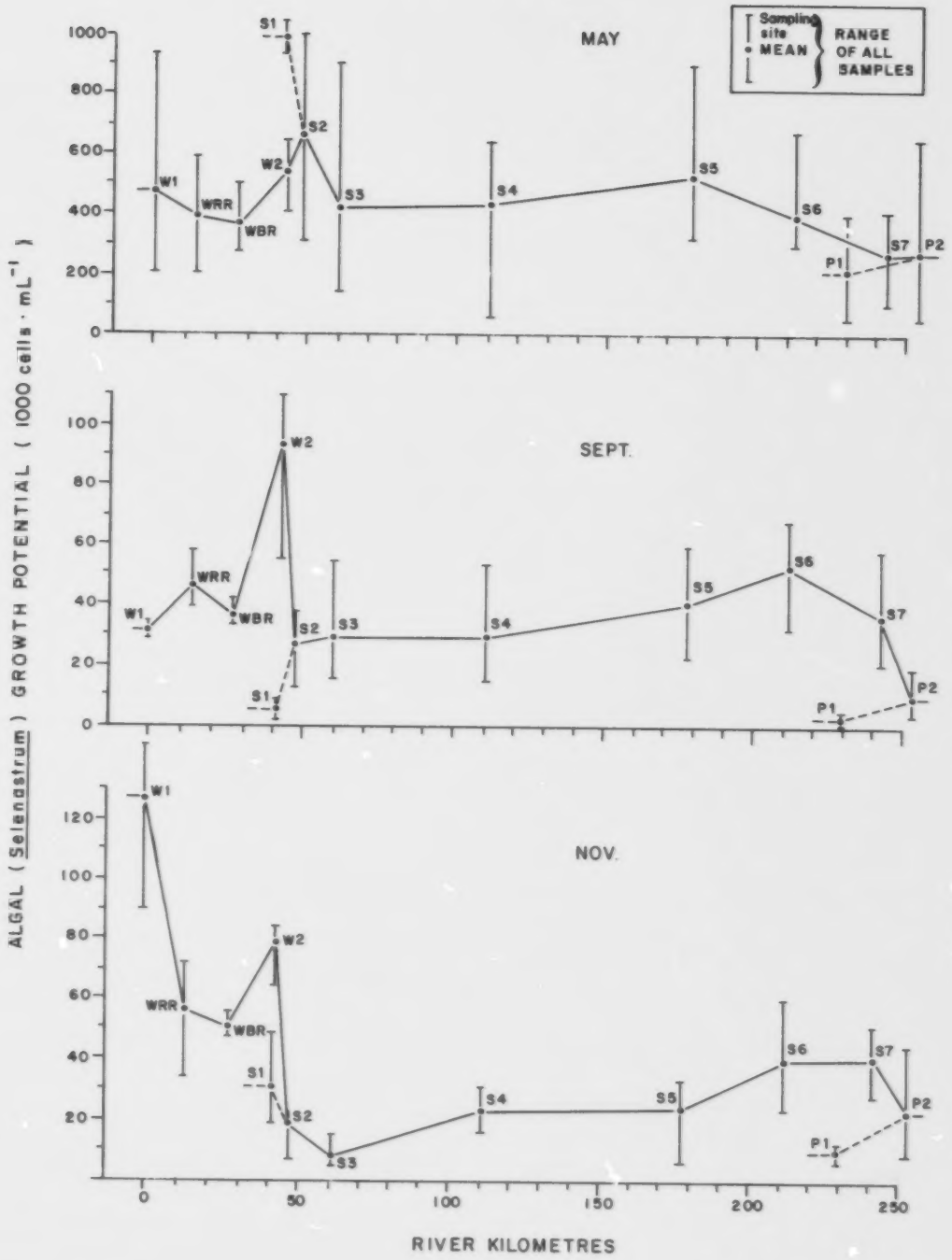

FIGURE 14. GROWTH POTENTIAL IN ALGAL ASSAYS, 1983.

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total phosphorus within each sampling period: in May, AGP declined when TP increased; in September the regression coefficient (r^2) was 0.44 for 11 samples; and in November the coefficient was only 0.038, for 11 samples. As noted, May AGP and TP were both much higher than in the other 2 months. However, high flows occurred in May and a number of water quality parameters besides TP were different then and may have contributed to the increased AGP.

3.4 Benthic Macroinvertebrates

3.4.1 Significance of the Benthos

As a group, benthic invertebrates are an important component of flowing-water ecosystems (Hynes 1970). They occupy several positions in the aquatic food web, from detritivores to carnivores (Merritt and Cummins 1978), and are major food items for many species of fish. They include a diverse assortment of taxonomic groups, which range from coelenterates (e.g., Hydra) to the more advanced insects, and they may be present on river beds in considerable abundance.

Benthic macroinvertebrates are frequently used in the assessment of water pollution (e.g., Warren 1971; Cairns and Dickson 1973; Hart and Fuller 1974). This is because of their importance in aquatic ecosystems and because they are a relatively easily sampled community which is abundant and diverse enough to be responsive to environmental changes. Relative to fish, benthic invertebrates are not too mobile which means their response to environmental factors is fairly site-specific. In addition, their generation and colonization times are long enough that once affected, the benthic community does

not immediately recover. Thus they can provide a record of transitory disturbances that is not obtainable by periodic water quality sampling.

3.4.2 General Conditions

A diverse assemblage of benthic macroinvertebrates was collected in spring and fall samples from the study area. Crustacea and Chironomidae dominated the spring samples numerically with Nematoda and Oligochaeta next in abundance (Appendix 14). Mean numbers of organisms per site ranged from 100 to 600/sample in spring, but were higher in the fall when mean numbers ranged from about 100 to over 3000/sample. This difference is normal for most flowing waters (Hynes 1970) since spring emergence of aquatic insects depletes their numbers and the effect of spring spates and ice breakup may further reduce the density of the benthos. Fall samples were dominated by Chironomidae but several other taxa were present as well. Oligochaeta and Plecoptera were next most abundant, with Nematoda, Crustacea, and Ephemeroptera about equal and next in abundance (Appendix 15). At the level of identification used in this study the mean number of taxa per sample had an upper limit of 24 in both spring and fall (Figures 15 and 16).

Some of the Crustacea collected in spring and fall samples likely entered the cylinder sampler in the drift and may not have been truly benthic in habit. Nonetheless, they were present and will have reflected water quality conditions to at least some extent, so they are included in the analysis.

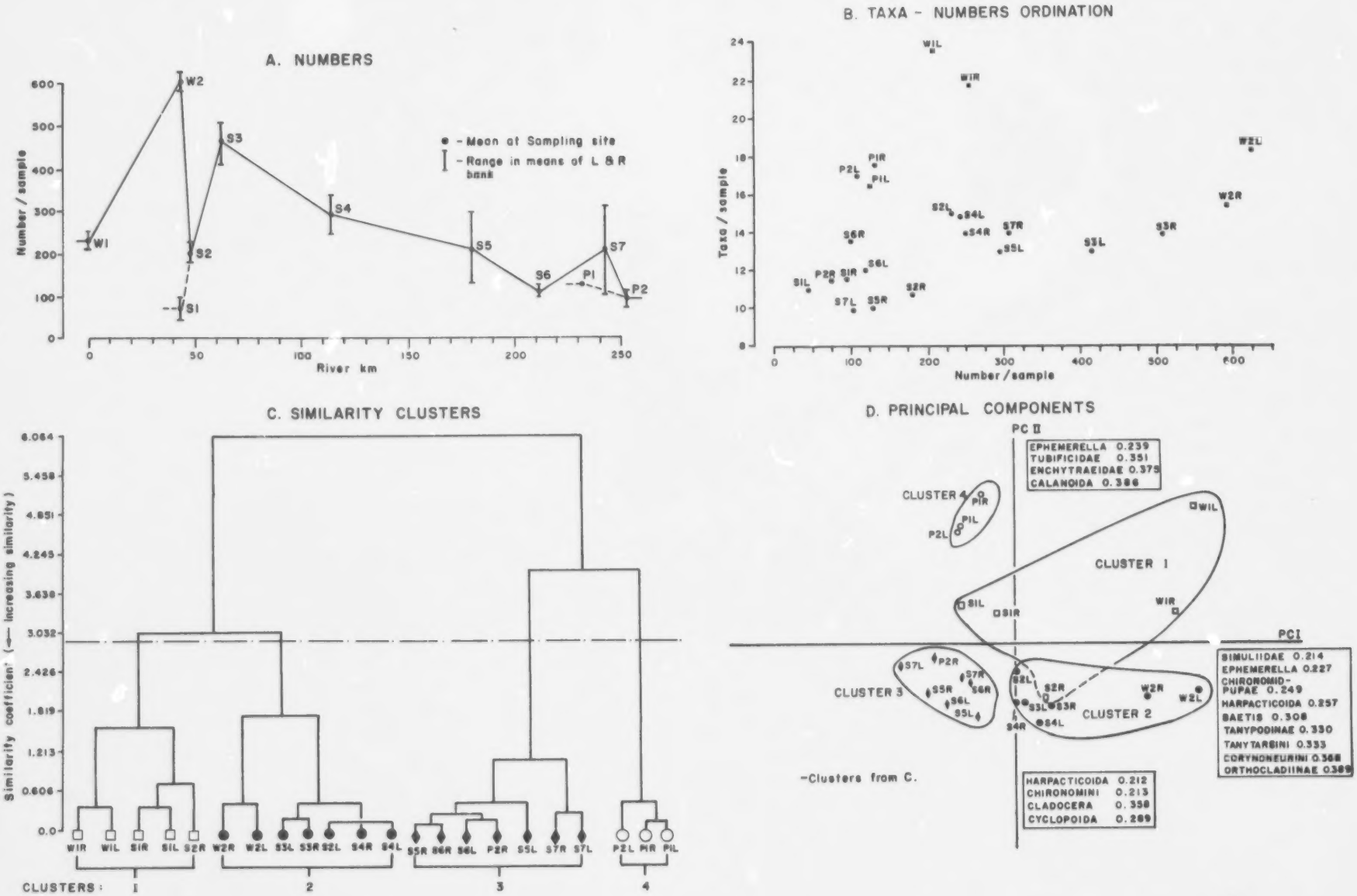

Figure 15. Benthic macroinvertebrate analysis, spring 1983.

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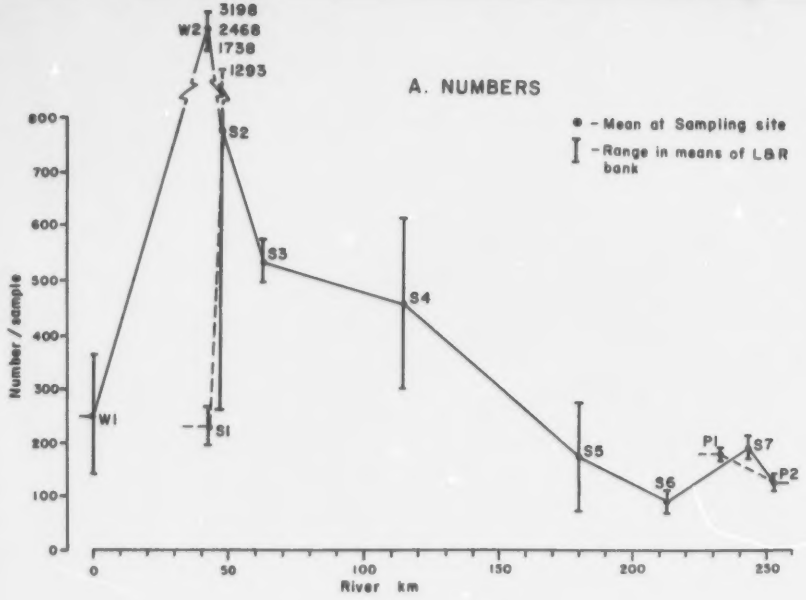

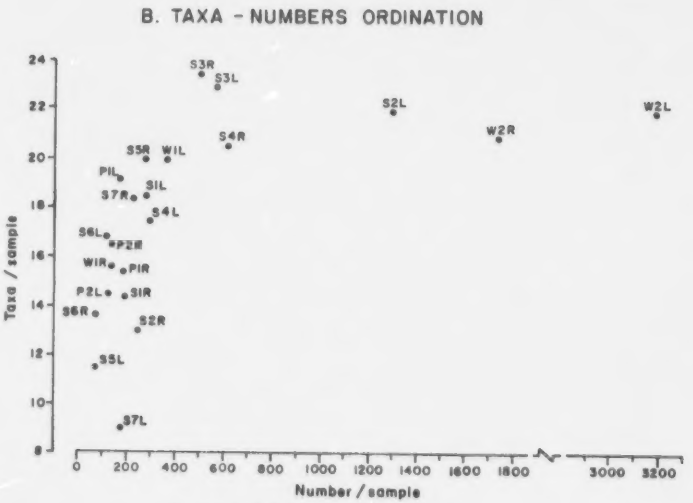

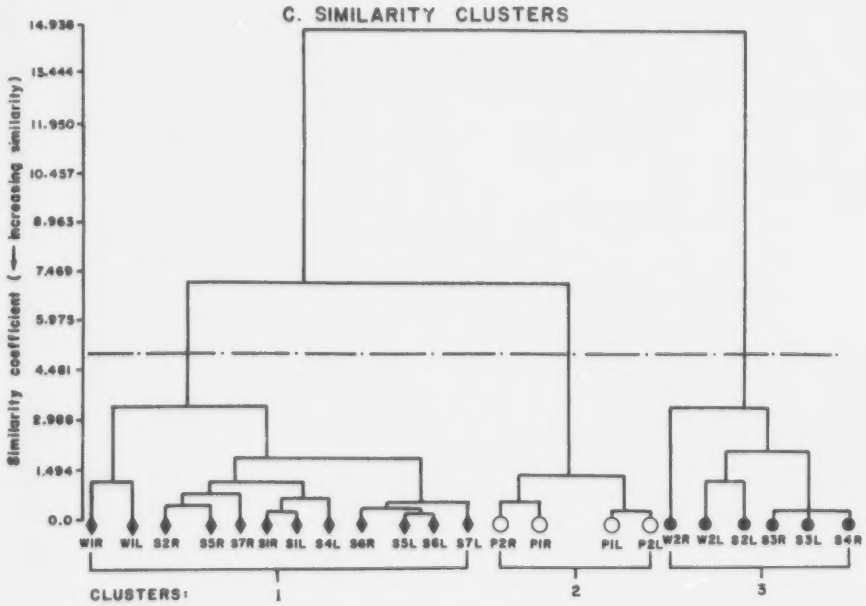

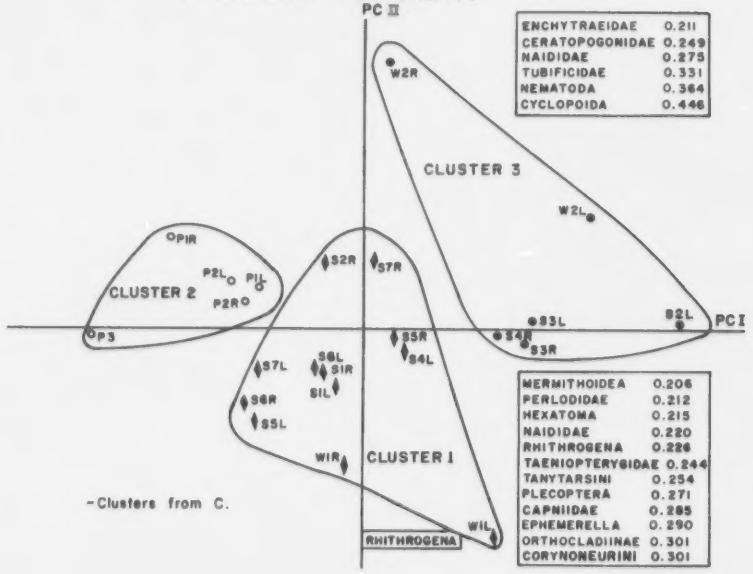

Figure 16. Benthic macroinvertebrate analysis, fall 1983.

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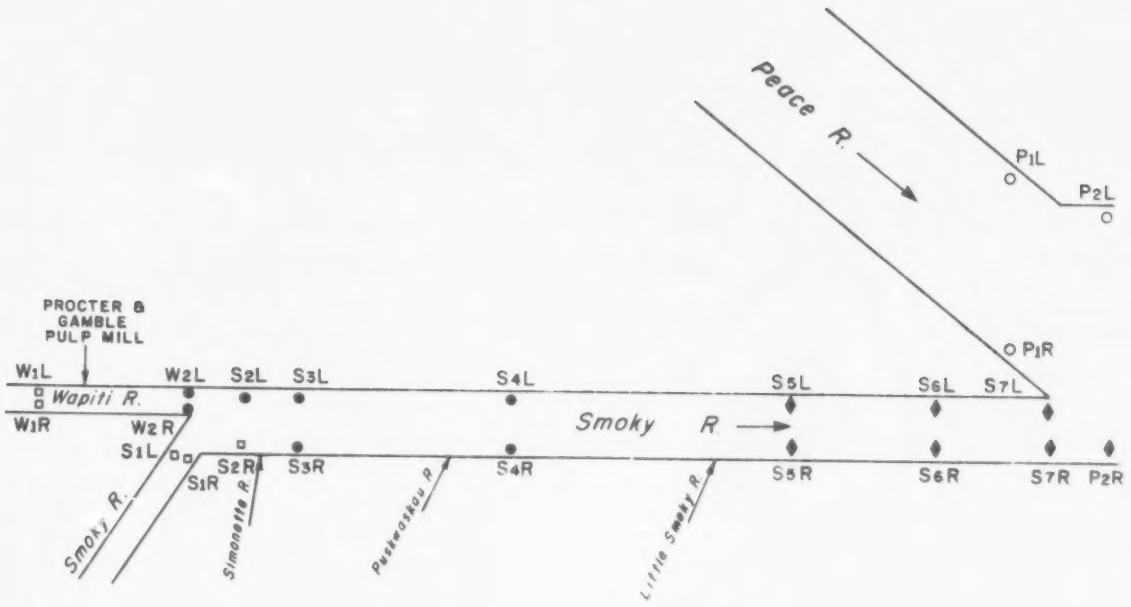
Elliott (1977) has suggested that a 20% level of precision (standard error as a percentage of the mean) is a reasonable goal for replicate benthic samples. The standard error in mean total per sample in this study was within 20% of the mean for 41 of 44 sample sets (Appendices 14 & 15) and sample precision is thus considered satisfactory.

3.4.3 Spring Samples

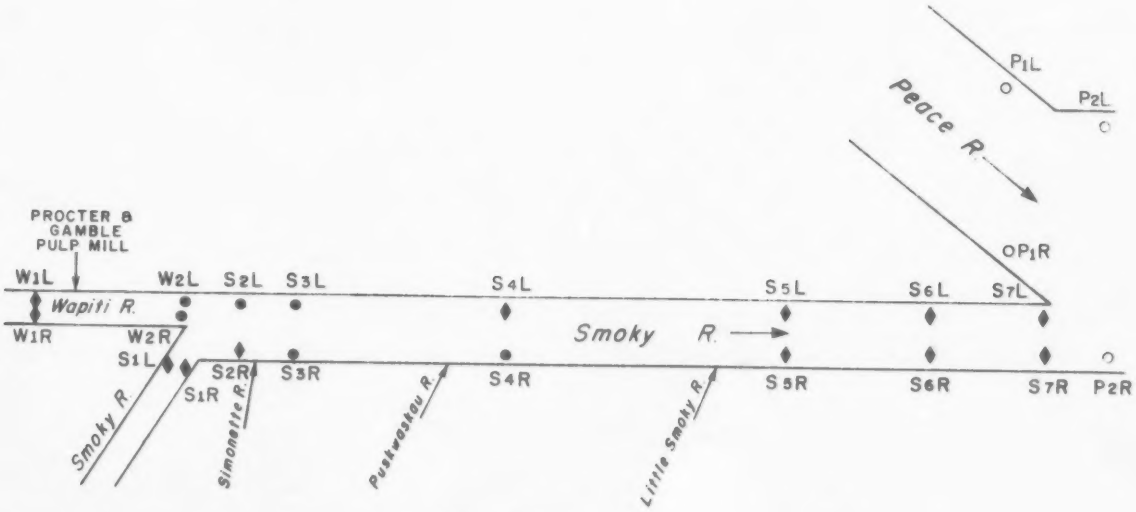
The number of benthic macroinvertebrates collected in the study area increased noticeably downstream of the mill effluent (Figure 15A). Numbers generally declined down the Smoky River to around 150/sample at the lower Smoky and Peace River sites. The increase in numbers at Sites W2 and S3 was mostly as a result of an increase in Crustacea (Appendix 14), which persisted in the samples down to about site S5 and then diminished.

The taxa versus numbers ordination (Figure 15B) also illustrates the increased numbers at sites W2 and S3 and shows that there was some drop in number of taxa from W1 to W2 in the Wapiti. Upstream Peace River sites were quite homogeneous regarding numbers and taxa and group closely on the ordination.

The cluster dendrogram (Figure 15C) groups sites according to the calculated similarity of their zoobenthic assemblage. It shows that in most cases, left and right bank samples were quite similar since they join at high similarity levels. The main exceptions to this are at S2 and P2, downstream of river confluences where mixing was incomplete, and such sites group with sites upstream in the respective rivers (Figure 17). The sites on the dendrogram can be



A. SPRING



B. FALL

Figure 17. Site groupings based on benthic cluster analysis.

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conveniently separated into 4 clusters at the 3.0 level of similarity. The clusters are also shown on the river schematic (Figure 17). Cluster 2, extending from Site W2 downstream to site S4, indicates a zone of probable influence of the wastewaters. Farther downstream the zoobenthos changed, and the remaining Smoky River sites plus P2R group into cluster 3, implying less wastewater influence in that area. The upstream controls plus S2R (probably in the upstream Smoky River plume) were fairly similar to one another and form Cluster 1. Peace River sites, excluding P2R in the Smoky River plume, form the 4th cluster.

Principal components analysis, (PCA) is a means of assessing the main taxonomic and numerical features that differ between samples and using these features (the 'principal components') as axes in a graph on which the samples or sites can be plotted and discriminated. PCA reveals that cluster 1, containing the control sites W1, S1, and S2R, had taxonomic features that varied markedly between the sites since the sites scatter over the graph (Figure 15D). This is not surprising since the sites are from different rivers. PCA also shows that Harpacticoida, Cladocera, Cyclopoida (these three groups are all Crustaceans) and Chironomini characterized cluster 2 which separates from cluster 1 on the vertical (PCII) axis. This is consistent with the observation earlier that increases in numbers at W2 and S3 resulted mostly from increases in Crustaceans. Cluster 3, which contains the downstream - most sites on the Smoky, separates from cluster 2 primarily by having fewer Chironomidae, Simuliidae, Harpacticoida, and Baetis.

3.4.4 Fall Samples

The numbers of invertebrates collected in fall samples ranged from 100 to over 3000/sample with a definite increase at W2 and S2 (Figure 16A). Numbers declined downstream in the Smoky River to Sites S6 and S7 where numbers were similar to those in Peace River samples. The increase in numbers from site W1 to W2 was due to a large increase in Oligochaeta, cyclopoid Crustacea and Chironomidae (Appendix 15). At S2, left bank samples were likely in the Wapiti River plume, and had much higher total numbers than right bank samples (S2R). Chironomidae and to a lesser extent Plecoptera were the most abundant organisms at all other Smoky River sites, thus indicating that the Wapiti River inflow only markedly changed the zoobenthic composition at S2. This influence is also reflected in the ordination of taxa versus numbers (Figure 16B) which separates sites W2L, W2R and S2L on the graph. It also shows that sites presumably affected by the wastewaters are generally enriched in numbers and also somewhat in taxa compared to other sites.

Sample sites are grouped into clusters based on their calculated similarity in Figure 16C. An obvious break point for the dendrogram is at the similarity level of 5.0. This produces 3 clusters of sites, the first comprising the upstream controls and the lower Smoky River sites. Cluster 3 contains Sites W2, S2L, S3, and S4R and appears to be a zone of wastewater influence, corresponding to the indications from numbers and taxa discussed above. Peace River sites group together in cluster 2 (Figure 16C and Figure 17).

In fall there seemed to be more dissimilarity between left and right banks at a site than in spring since left and right sites did not join as often on the dendrogram as in spring (Figure 15C and 16). This greater dissimilarity may be due to a generally more stable or declining flow regime in late summer-fall (Figure 2) which permitted the zoobenthic community at each site to develop and diverge more fully. In contrast, the spring break-up and spate has a depletional and homogenizing effect.

Fall benthic samples are graphed on the two principal components which explain most of the variance in the benthic data set (Figure 16D). Cluster 3, which contains the 'affected' sites separates by virtue of having higher numbers of several taxa, mainly Chironomidae, Ephemeroptera, and Plecoptera. This is consistent with the taxa versus numbers ordination and further describes the nature of the effect: density, and secondarily, taxon richness are increased in the Wapiti and Smoky Rivers and organisms typical of "clean water" (Ephemeroptera and Plecoptera) appear to be enhanced as well as other types.

3.4.5 General Effects

Benthic macroinvertebrate data indicate that this community of aquatic organisms in the Smoky and lower Wapiti River was being affected by upstream wastewaters. Both spring and fall analyses showed a cluster of similar sites from W2 to about S4-S5, which was the zone of measurable effects on the benthos (Figure 17). The effect was generally one of enrichment, primarily of number of organisms but also of number of taxa. Distinct reductions in numbers or taxa were

not apparent at the sampling sites, which for this study were concentrated in the Smoky River.

The enrichment likely results mainly from the organic and nutrient load discharged to the river system by the pulp mill. However, wastewaters from Grande Prairie entering via the Bear River may also contribute to the observed effect by adding organic and inorganic nutrients. All such inputs would tend to stimulate bacterial and algal growth on the river bed, which would provide a greater food base to permit greater densities of invertebrates. Such effects have been observed in other areas (Hynes, 1960; Bothwell and Stockner 1980; Webb 1985; Rabeni et al. 1985).

The benthic investigations in this and many studies are confined to shallow areas of river (<1 m depth) because of equipment limitations. The effects in deeper waters are not known, but this is relevant in pulp mill assessments since discolouration is a common effect and it can reduce light penetration with consequent reductions in photosynthesis and biological productivity (Poole et al. 1978). Thus the increased colour downstream of the pulp mill may have counteracted the increased nutrient load and the net effect on aquatic productivity in the total channel of the receiving rivers is not known.

No direct or clear evidence of acute toxicity to, or inhibition of, the zoobenthos by the pulpmill effluent was observed. Even though locations close to the pulp mill effluent were not sampled, this finding is consistent with recent biological surveys on the Wapiti River commissioned by Procter and Gamble Cellulose Ltd (filed with Alberta Environment). Previous benthic monitoring by

Alberta Environment indicated little effect of the mill effluent in the mid-1970's. In 1980, following low river flows and water quality impacts at Peace River town, benthic monitoring by Alberta Environment indicated the pulp mill effluent was causing a noticeable reduction in numbers of the zoobenthos in the Wapiti River. It appears that the impact has lessened since 1980. Historically, much of the adverse impact on aquatic biota documented in the literature has resulted from pulp mill effluents with little or no treatment (reviews by Poole et al. 1978; Kovacs 1986; D. McLeay and Associates 1987). Those with secondary biological treatment, as at Procter and Gamble, generally have not been linked with distinct, toxic effects.

4.0 GENERAL DISCUSSION

The most significant effluent from the Procter and Gamble Cellulose Ltd. pulp mill is the effluent from the aerated treatment lagoons (the 'final effluent'). This effluent contains high concentrations of salts, organic compounds, nutrients, and bacteria, and is discharged to the Wapiti River with resulting measurable increases in these parameters in the Wapiti and Smoky rivers during low to moderate flows. High river flows dilute the effluent and prevent noticeable changes in river water quality. Benthic organisms in shallow areas of the Smoky and lower Wapiti rivers appear enriched or 'fertilized' by the mill effluent although wastewaters from Grande Prairie may also contribute to this effect.

These effects are what can be expected to occur most of the time downstream of the mill since during this study the mill was largely in compliance with its licence limits and river flows were near average. The effluent characteristics and water quality effects are in keeping with the findings of other studies on pulp mills with secondary effluent treatment (e.g. D. McLeay and Associates 1987; Whitfield and Oliver 1983). During lower flow periods, greater impacts would be expected.

4.1 Organics

The composition of the dissolved organic material in the mill's final effluent is not fully known. If it is assumed to be carbohydrate (CH_2O) a reasonable balance results with the total filterable residue and total inorganic dissolved solids (Section 3.2.4.3). However, on the sampling occasions during this study, the fate of the dissolved organic carbon (DOC) seemed to be mainly dilution and downstream transport. This is in contrast with the possibility of the DOC being carbohydrate since carbohydrates are normally readily taken up and utilized by stream organisms. The exact identity of most of the organic compounds remains unknown except that trace organic analyses show they are not 'priority pollutants'.

4.2 Bacteria

The mill final effluent and perhaps also Grande Prairie's wastewaters, appeared to cause increases in fecal coliforms in the Wapiti and Smoky rivers. As noted, the exact identity of these bacteria is not known nor is their pathogenicity. Pulp mill effluents

are known to contain forms of Klebsiella which can not be differentiated from pathogenic forms (Health and Welfare Canada 1983). However, there is apparently no evidence that Klebsiella in surface waters produces disease (Duncan 1988). River samples complied with the ASWQO for fecal coliforms but not always for total coliforms.

4.3 Compliance

The pulp mill effluents were largely in compliance with their licence limits during this study. The occasional non-compliant events were minor and did not increase the water quality effects observed in the receiving rivers. In the rivers, non-compliance with the ASWQO was observed for colour, phenols, phosphorus, manganese, and possibly bacteria and was probably attributable to the pulp mill.

Non-compliance was greater at low flows. Odour was difficult to analyze and its compliance is uncertain. The parameters not covered by the ASWQO but addressed by the CWQG all complied with the CWQG except aluminum, which exceeded guidelines naturally in the rivers. The observed compliance is strongly influenced by sample timing - more frequent sampling during low flows would paint a worse picture. Also, sampling was concentrated in the Smoky River, whereas water quality effects are likely most pronounced in the Wapiti River (this study was focused on the Smoky because little investigation had been carried out there).

4.4 Effects on Use

4.4.1 Drinking Water and Municipal Supply

The non-compliance observed above may have some negative effects on water use. The quality does not meet drinking water guidelines and therefore is not suitable for direct use, although such use is likely rare or non-existant and surface waters are not expected to be potable without some treatment. Nonetheless, local domestic usage could be impaired by the effects on colour, phenol, Mn, odour and bacteria. The suitability of the water as supply to a municipal treatment plant could be impaired since the colour, phenol, and manganese effects would likely necessitate more intensive treatment measures. The town of Peace River dealt with similar problems in 1980 by avoiding the Smoky River plume and moving their intake to the left bank of the Peace River. Future municipal usage of the Wapiti-Smoky rivers downstream of the pulp mill is not known.

4.4.2 Recreation

Recreational usage of the Wapiti and Smoky rivers could have been impaired by the observed non-compliance since aesthetic (colour) and health (bacteria) parameters were exceeded at times. Odour was difficult to analyze but complaints from residents indicate that it was deleterious to recreational usage on some occasions (Alberta Environment files). The source of the odours was associated with the pulp mill by the complainants, although direct corroboration of this is not available. Complaints have also occurred about 'slime' on the river bed, which may detract from the aesthetic quality of receiving waters. Such 'slime' may include a diverse assemblage of algae,

bacteria, fungi, protozoans and associated sediment and occurs to at least some extent in essentially all rivers. However, it can be augmented by effluents enriched in organic and inorganic nutrients such as pulp mill wastes and municipal sewage (e.g. Hynes, 1960; Bothwell and Stockner 1980; Webb 1985). No direct measurements of this aspect were made in 1983 but it is probable that such benthic growth was stimulated to at least some extent since benthic macroinvertebrates showed such a response. Both the mill effluent and Grande Prairie wastewaters may have contributed to this.

4.4.3 Aquatic Life

As described earlier, the effect observed on aquatic life (benthic macroinvertebrates in this case) seemed to be enrichment or fertilization, likely due to some combination of the pulp mill effluent and Grande Prairie wastewaters discharging nutrient material. These effects are not necessarily related to the non-compliant parameters listed above (Section 4.3) since they could result from organic loading alone which is not directly covered by the ASWQO or CWQG. That is to say, river quality could be 100% compliant and these effects on the benthos could still occur.

Other effects of the pulp mill discharge on aquatic biota were not investigated. Of the non-compliant water quality parameters noted above, phenols may adversely affect aquatic organisms through toxic action or tainting of sport fish. An assessment of the latter has been carried out by the Alberta Environmental Centre (1987). Discolouration may depress biological productivity in the river by

reducing light penetration, thus counteracting the enriching effect noted above.

4.4.4 Agricultural

Water quality at the sampling sites in the receiving rivers met most guidelines for agricultural use (irrigation and stockwatering). The exception was total coliform bacteria in May samples, which exceeded the ASWQO for vegetable crop irrigation. This non-compliance may have been partly attributable to the mill effluent although other wastewaters and the generally high bacterial densities in May may also have contributed to the exceedance. Odour was difficult to measure during the study and its effect on stockwatering is uncertain. Complaints have arisen in the past about pulp mill-like odours impairing the Wapiti and Smoky rivers for this use.

5.0 CONCLUSIONS

The Wapiti-Smoky River system was sampled on four occasions in 1983 to assess water quality impacts of the Procter and Gamble pulp mill, and to augment the data base and understanding of the river system. The findings are:

- Annual flows and flows during sampling occasions were near average in 1983. The mill's final effluent constituted from 0.2% (May) to 6% (March) of the flow in the Wapiti River when sampled in this study.
- Compared to background sites in the Wapiti and Smoky rivers, the final effluent was higher in the following parameters:

50-500 times higher:	Na^+, Cl^-, colour, phenolics, tannin & lignin, COD, DOC, fecal coliforms
5-50 times higher:	K^+, $SO_4^=$, filt. residue, TDS, conductance, BOD, odour, NH_3-N, TKN, total P, Mn, Zn, total coliforms

3-5 times higher: Ca^{+}, SiO_2, hardness, Cd, Cu, Fe, Pb.

This effluent also contained trace organic contaminants such as dimethyl sulphides, chlorophenols, chloroform, and chlorinated ethylenes. The storm sewer/cooling water effluent was generally more dilute, lower in volume, and had no discernible effect on river water quality.

- River quality downstream was affected by the final effluent in proportion to the parameter increases described above, and in inverse proportion to river flow and dilution. Observed effects were greatest in March and least in May:

  Major inorganics - Downstream increases were greatest for Na^{+} (increased from 5 to 25 $mg \cdot L^{-1}$ in Smoky River) and Cl^{-} (increased from 2 to 20 $mg \cdot L^{-1}$ in Smoky). NFR was slightly increased at low flow in the Wapiti River. Oxygen was not markedly affected.

  Conventional organics - Phenolics, tannin and lignin, colour, and DOC were raised by the final effluent on 3 of the 4 occasions, the increases being observable down the length of the Smoky River. Some increase in odour was also observed but odour was difficult to quantify.

  Trace organics - Dimethyl sulphides were not detected in river samples but chlorinated organics, principally chloroform, were detected at low levels down to Site S5 (Watino) in March.

  Nutrients - NH_3-N and total P were increased downstream during low flows but Grande Prairie wastewaters may also have contributed to this effect.

  Metals - Mn and Zn were the only metals notably elevated in the final effluent and some downstream increase resulted, but only during low river flows and mainly in the Wapiti River.

  Bacteria - Downstream increases were observed in heterotrophic bacteria (SPC), fecal coliforms, and total coliforms. Part of this may be attributable to the pulp mill effluent but part may be attributable to Grande Prairie wastewaters.

- Compliance of samples with pertinent limits was as follows:

  Licence to Operate - The final effluent complied with limits for BOD, COD, odour, pH, and toxicity and probably for suspended solids. The storm sewer cooling water complied for pH, and suspended solids. For COD it complied in 6 out of 8 samples.

ASWQO - 11 of 21 parameters complied in all river samples. Total N, Cr, Cu, Fe, Hg, and Zn were occasionally non-compliant due to natural causes. Non-compliance attributable to the pulp mill was observed for colour, phenols, total P, and Mn, primarily during low flow conditions in both rivers. Total coliforms were also non-compliant, the pulp mill and other factors being possible contributors.

CWQG - 19 parameters, not addressed by ASWQO, complied with the CWQG for the most sensitive use (excl. industrial uses). Aluminum exceeded the CWQG naturally and was not affected by pulp mill effluents.

USEPA 1986 - Two remaining parameters (carbon tetrachloride, dichloroethylene) complied with aquatic toxicity criteria.

- Algal assay results were quite variable and no consistent effect of the pulp mill was observed. AGP was much higher overall in May than in September or November.

- Benthic macroinvertebrates in shallow water areas of the Smoky and lower Wapiti rivers appeared to be enriched in numbers and to some extent in taxa as a result of the pulp mill effluent and possibly Grande Prairie wastewaters. The effect was observable downstream to about Watino.

- The water quality effects of the pulp mill effluent may affect suitability for use:

  Potable supply - Domestic and potential municipal usage may be impaired by colour, phenols, Mn, and perhaps odour and bacteria effects.

  Recreation - Colour, bacteria, and potentially odour and benthic 'growths' may impair recreational use. Grande Prairie wastewaters may also have contributed to the bacteria and benthic effects.

  Aquatic life - Increased nutrient loading stimulates some components of the rivers' biotic communities but increased colour may inhibit others.

  Agricultural - Use for stockwatering may be impaired by odour effects, but quantification of odour in the downstream river samples was not fully obtained.

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APPENDIX 1 Water Quality Parameters and Analytical Methods

Parameter	Container	Preservation	Analytical Code	Analytical Method Or Instrument
Field Analysis				
Temperature			02061F	Field meter
pH			10301F	Field meter
Conductance			02041F	Field meter
Oxygen, dissolved			08101F	Azide-Winkler method
Lab Analysis				
pH	P	Cool to 4°C	10301L	Meter
Ca	P	Cool to 4°C	20110L	Automated atomic absorption
Mg	P	Cool to 4°C	12303L	Atomic absorption, direct aspiration
Na	P	Cool to 4°C	11103L	Flame photometer
K	P	Cool to 4°C	19103L	Flame photometry, internal standard
HCO_3			06201L	Calculated
Cl	P	Cool to 4°C	17203L	Colourimetry, ferric ammonium sulfate and mercuric thiocyanate
SO_4	P	Cool to 4°C	16306L	Colourimetry, $BaCl_2$ and methylthymol blue
SiO_2	P	Cool to 4°C	14102L	Heteropoly blue colourimetry
F	P	Cool to 4°C	09107L	Automated potentiometric method
Conductance	P	Cool to 4°C	02041L	Meter
Total dissolved solids			00205L	Calculated
T. hardness			10602L	Calculated, as $CaCO_3$
Total alkalinity	P	Cool to 4°C	10101L	Potentiometric titration
Total residue			10474L	Calculated
Filterable residue	P	Cool to 4°C	10453L	Gravimetric
Non filterable Residue	P	Cool to 4°C	10407L	Gravimetric (0.45 μm filter)
NO_2+NO_3-N	P	Cool to 4°C	07105L	Colourimetry on autoanalyzer
Nitrite-N	P	Cool to 4°C	07205L	Colourimetry on autoanalyzer
Ammonia-N	P	2ml 5% H_2SO_4	07562L	Colourimetric analysis
Total Phosphorous	P	2ml 5% H_2SO_4	15421L	Colourimetry on autoanalyzer
Total Kjeldahl Nitrogen	P	2ml 5% H_2SO_4	07021L	Colourimetry on autoanalyzer
T. Nitrogen, particulate	P		07906L	Thermal conductivity
Biochemical oxygen demand	G	Cool to 4°C	08202L	5 day, 20°C
Chemical oxygen demand	P	2ml 5% H_2SO_4	08304L	Semi-automated colourimetry
C, dissolved organic	P	Cool to 4°C	06107L	Colourimetry
C, dissolved inorganic	P	Cool to 4°C	06154L	Colourimetry
C, Total	P	Cool to 4°C	06905L	Thermal conductivity
Phenols	G	1:1 H_2SO_4	06537L	Automated 4-aminoantipyrine colourimetry

APPENDIX 1 Cont'd

Odour	G	Cool to 4°C	02001L	Threshold dilution number
Tannin and Lignin	G	Cool to 4°C	06551L	Filtered if turbid: acid colourimetry
Colour, true	G	Cool to 4°C	02022L	Spectrophotometric, Pt-Co standard (H5P method)
Oil and Grease	G	1:1 H_2SO_4	06524L	Freon extraction and IR spectrophotometry
Fe (extr)	P	Cool to 4°C	26304L	Atomic absorption, direct aspiration
Cr +6 (diss.)	P	1:1 HNO_3	24101L	Colourimetric with diphenylcarbazide
Hg (total)	P	HNO_3-$K_2Cr_2O_7$	80015L	Flameless atomic absorption
Co (total)	P	1:1 HNO_3	27009L	Atomic emission spectrometry (ICAP)
Cu (total)	P	1:1 HNO_3	29009L	ICAP method
Ni (total)	P	1:1 HNO_3	28009L	ICAP method
Cd (total)	P	1:1 HNO_3	48009L	ICAP method
Pb (extr.)	P	1:1 HNO_3	82302L	Atomic absorption, solvent extraction
Zn (total)	P	1:1 HNO_3	30009L	ICAP method
Mn (total)	P	1:1 HNO_3	25003L	ICAP method
Cr (total)	P	1:1 HNO_3	24009L	ICAP method
Be (extr)	P	1:1 HNO_3	04304L	Atomic absorption, solvent extraction
V (total)	P	1:1 HNO_3	23009L	ICAP method
Mo (total)	P	1:1 HNO_3	42009L	ICAP method
Al (extr)	P	1:1 HNO_3	13306L	Atomic absorption, solvent extraction
Se (total)	P	1:1 HNO_3	34005L	Goulden and Brooksbank (1974) method
As (total)	P	1:1 HNO_3	33005L	Goulden and Brooksbank (1974)
<u>Bacteria</u>				
Total coliforms	G	Cool to 4°C	36002L	Membrane filtration (EPS)
			36001L	Tube dilution (Prov. Lab.)
Fecal coliforms	G	Cool to 4°C	36012L	Membrane filtration (EPS)
			36011L	Tube dilution (Prov. Lab.)
Fecal streptococci	G	Cool to 4°C	36102L	Membrane filtration (EPS)
Standard plate count	G	Cool to 4°C	36905L	Agar plate at 35°C (EPS)
Toxicity		Cool to 4°C		Static 96 hr. multiple concentration LC_{50}, Rainbow Trout (Alberta Environment 1978)

P - polyethylene container G- Glass container
Analytical codes and methods: see Environment Canada (1986), and Alberta Environment (1981).

APPENDIX 2 Priority Pollutant Analysis Methodology

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The method employed for extractable priority pollutants in the MD&RS Section is based on the EPA Method 625 and covers the analysis of a number of organics that are partitioned into an organic solvent and are amenable to capillary gas chromatography/mass spectrometry (GC/MS). The method for purgeable priority pollutants is based on EPA Method 624 and deals with organics that are purged from water onto a trap, then desorbed and analyzed by capillary GC/MS.

The surface water is collected in the field directly into pretreated one litre amber sample bottles and stored in a refrigerator at 2-5°C until the time of analysis. The entire one litre volume of sample is serially extracted with methylene chloride at a pH greater than 11 and again at a pH less than 2 using a separatory funnel. The methylene chloride extracts are dried and concentrated, ready for GC/MS analysis.

Mass spectrometric/gas chromatographic analysis permit the separation and measurement of the organics in the extract. Qualitative screening is performed on target compounds using the relative retention time and relative abundances of three characteristic ions from the GC/MS data of the components of the extract. A full identification of organics screened in this manner is performed using full reference spectra. Quantitative analysis is performed using a multi-internal standards technique in which the integrated areas of characteristic ions are utilized in the calculation. Unknown compounds are identified based on comparsion with library spectra. Quantification of these non-target compounds (those that are not listed as priority pollutants) is accomplished by comparision of response with an appropriate internal standard.

The method employed for volatile or purgeable priority pollutants is the purge-and-trap technique. A sample volume of 200 mL is purged with an inert gas, helium. A Tenax trap adsorbs the volatile organics purged out of solution. This is followed by thermal desorption of the volatiles on the trap onto a GC column, and subsequent mass spectral analysis. Qualitative and quantitative analysis are performed in the same fashion as for extractable priority pollutants.

APPENDIX 3 Mean Monthly Flows For 1983 and The Period of Record

	Wapiti River GE001		Final Effluent	Storm Sewer/ Cooling Water	Simonette River GF001		Little Smoky River GH002		Smoky River at Watino GJ001		*Peace River at Peace River HA001	
	1960-84	1983	1983	1983	1970-84	1983	1960-84	1983	1915-84	1983	1970-84	1983
January	14.6	12.5	51,500	3900	2.6	2.5	5.0	4.5	53.2	47.7	1280	1040
February	13.6	10.4	53,700	3600	2.4	2.0	4.7	4.7	44.2	38.2	1215	634
March	13.7	10.0	50,300	2750	3.2	2.8	6.3	5.3	47.5	38.9	1180	573
April	84.7	93.3	42,500	7000	46.3	15.7	105.0	19.7	363.0	223	1910	1160
May	268	200	56,600	1500	80.7	29.7	159.0	35.5	882.0	469	2880	2350
June	330	238	58,600	4140	64.8	86.3	116.0	133	1080.0	859	3270	2590
July	208	287	57,500	8600	50.0	176	99.2	293	761.0	1300	2680	4690
August	103	67.7	56,800	7550	27.1	36.8	62.5	90.5	431.0	409	1830	1960
September	79.3	42.0	57,700	6040	20.3	20.2	42.1	35.6	293.0	214	1580	1890
October	78.5	34.6	49,700	5100	16.5	11.1	24.7	21.4	235.0	137	1690	1640
November	37.5	31.3	53,800	2140	6.7	9.4	12.4	19.7	117.0	117	1550	1410
December	20.0	13.3	52,300	1700	3.8	3.2	7.3	9.5	64.1	58.2	1460	1520
Annual	105.0	87.1	53,400	4500	28.3	33.2	52.7	56.5	367.0	328	1880	1800

Rivers as $m^3 \cdot s^{-1}$; effluents as $m^3 \cdot d^{-1}$
Data from Environment Canada 1985 and Procter and Gamble monthly reports.
*Regulated flows.

APPENDIX 4 Daily Discharge During Sampling Trips, 1983

Date		W1 GE001	SS/CW	FE	Simonette River GF001	Little Smoky River GH002	S5 (Smoky River) GJ001	P2 (Peace River) HA001
March	12	9.44	2745[1]	40500	2.92	5.70	36.7	585
	13	9.47		44400	2.92	5.63	37.6	584
	14	9.50		52300	3.03	5.54	38.1	574
	15*	9.61		49700	3.01	5.47	39.3	567
	16*	9.72		51000	3.01	5.42	39.9	555
	17*	9.90		49700	3.12	5.37	40.9	541
May	8	276	1500	60100	40.0	29.0	382	1670
	9	275		62700	53.5	45.0	559	1770
	10*	249		47100	53.0	61.5	587	1860
	11*	215		58800	49.1	57.5	565	2230
	12*	188		57200	43.0	57.0	503	2580
September	25	40.7	6035	52300	17.6	35.8	191	1880
	26	39.9		54900	16.0	35.0	187	1930
	27*	37.8		54900	14.9	32.4	180	1880
	28*	36.9		52300	14.0	29.7	174	1930
	29*	37.8		57500	13.5	28.6	175	2010
October	30	50.0	5100	52300	11.7	17.2	198	1770
	31	46.6		57500	11.4	19.0	175	1620
November	1	52.4	2143	61400	11.8	18.9	166	1690
	2*	57.2		56300	13.5	18.7	171	1630
	3*	53.9		54900	18.1	22.7	206	1690

* Water quality sampling. [1]Monthly mean
GE001 - Flow Station number of Water Survey Canada
Flows as $m^3 \cdot s^{-1}$ except SS/CW and FE, as $m^3 \cdot d^{-1}$

APPENDIX 5 Selected Cross Channel Concentrations, 1983

Parameter	Site	15-17 March		10-12 May			27-29 September			2-3 November	
		R	L	R	C	L	R	C	L	R	L
Na											
	S3	24	23	7	7	8	11	10	10	9	9
	S5	24	25	9	9	9	10	10	10	9	8
	S6	24	25	8	8	8	10	13	9	9	9
NFR											
	S3	10	13	619	558	326	14	14	14	25	25
	S5	9	14	595	781	836	20	20	20	21	17
	S6	4	6	806	806	793	37	20	28	24	22
TKN											
	S3	0.25	0.35	1.10	1.15	1.10	0.20	0.26	0.22	0.22	0.24
	S5	0.50	0.35	1.10	1.25	1.15	0.30	0.28	0.24	0.28	0.24
	S6	0.16	0.12	1.20	1.20	1.20	0.26	0.24	0.26	0.24	0.24
TOTAL P (ug/L)											
	S3	40	45	575	538	495	18	20	16	34	34
	S5	40	40	650	650	650	30	30	28	28	28
	S6	26	24	680	680	650	34	28	32	28	32
DOC											
	S3	6.6	6.5	9.7	8.7	8.6	3.6	3.5	3.5	3.0	3.0
	S5	6.0	6.1	9.4	9.3	9.3	5.9	5.5	5.4	4.4	3.9
	S6	6.1	7.0	9.2	9.3	8.0	5.8	5.9	5.7	4.1	4.2

Results as $mg \cdot L^{-1}$ unless noted

APPENDIX 6 Water Quality Data, 1983.

Date	Site	Locat	pH (units) 10301L	conduct uS/cm 02041L	Fe (extr) 26304L	TDS (calc) 00202L	Ca 20110L	Mg 12303L	t. hard 10602L	Na 11103L	K 19103L	silica 14102L	N02&N03 N 07105L	N02-N 07202L	F 09107L	Cl 17203L	SO4 16306L	HCO3 06201L	t. alk 10101L	BOD 08202L	COD 08304L	DOC 06107L	TC(part) 06905L	DIC 06154L	Residue total 10474L	Residue filt. 10453L	NFR 10407L	NH3-N 07562L	P total 15421L
15-Mar-83	P66	FEB	7.5	5190	0.79	2908	255	18	711	790	13.7	12.7	0.10	0.10	0.15	1150	450	469	385	63.0	1119.2	254.0	49.00	88.0	3490	3280	210	0.170	1.800
16-Mar-83	P66	FEB	7.5	5090	0.83	2957	260	18	724	780	14.0	11.7	0.08	0.08	0.16	1150	500	477	391	70.0	1119.2	288.0	56.00	90.0	3622	2520	102	0.150	1.700
10-May-83	P66	FEB	7.5	4270	0.58	2397	192	12	529	710	11.0	9.8	0.12	0.12	0.06	930	396	296	243	57.0	837.5	210.0	29.00	60.0	3346	3140	206	0.010	0.900
11-May-83	P66	FEB	6.8	4170	0.56	2231	171	12	477	650	11.0	9.0	0.12	0.12	<.05	870	380	278	228	33.0	792.9	210.0	18.00	52.0	3058	2840	218	0.360	0.700
27-Sep-83	P66	FEB	7.3	4630	1.08	2669	245	18	686	730	11.6	10.9	<.05	<.05	0.06	1100	370	394	323	47.7	986.5	266.0	45.70	72.0	3525	3190	335	0.120	1.250
28-Sep-83	P66	FEB	7.5	4710	1.17	2706	235	18	661	730	13.2	11.4	<.05	<.05	0.06	1150	360	406	333	43.0	998.2	249.0	48.10	78.0	3704	3350	354	0.007	1.600
02-Nov-83	P66	FEB	7.4	4090	2.72	2414	153	16	448	715	22.1	8.9	<.05	<.05	0.08	715	595	402	330	31.0	698.5	187.0	0.96	75.0	3007	2990	17	0.019	0.950
03-Nov-83	P66	FEB	7.1	4120	1.08	2448	156	14	447	720	21.6	8.8	<.05	<.05	0.09	730	610	399	327	39.0	731.0	199.0	11.80	79.0	3097	2990	107	0.014	0.950
10-May-83	P66	FEC	6.7	4250	0.57	2223	179	11	493	650	9.8	8.5	0.12	0.12	0.06	860	372	286	235	33.3	743.6	220.0	27.00	58.0	3144	2930	214	0.480	0.850
27-Sep-83	P66	FEC	7.7	4640	1.09	2722	225	18	636	750	13.2	11.2	<.05	<.05	0.06	1125	390	407	334	41.5	981.4	250.0	38.85	77.0	3588	3250	338	0.140	2.520
02-Nov-83	P66	FEC	7.6	4110	1.07	2428	156	14	447	685	21.0	8.9	<.05	<.05	0.11	710	645	400	328	35.0	698.5	192.0	2.70	71.0	2990	2930	60	0.012	0.950
15-Mar-83	P66	SS/DW	7.9	241	0.06	128	22	6	80	11	0.8	3.3	0.07	<.05	<.05	2	45	83	68	<1	<5	1.2	0.22	15.0	166	160	6	0.058	0.010
16-Mar-83	P66	SS/DW	8.5	236	0.04	126	20	7	79	12	0.9	3.2	<.05	<.05	0.11	<1	50	64	57	<1	<5	1.2	0.16	13.0	234	230	4	0.058	0.008
10-May-83	P66	SS/DW	7.3	374	4.43	222	48	7	149	12	1.2	2.5	<.05	<.05	<.05	2	104	97	80	8.0	306.4	6.4	120.00	22.0	5746	400	5346	0.068	3.200
11-May-83	P66	SS/DW	6.6	340	3.53	193	43	7	136	14	2.2	1.9	<.05	<.05	0.09	2	70	110	90	2.5	238.4	16.0	83.00	24.0	3319	230	3089	0.100	0.205
27-Sep-83	P66	SS/DW	7.5	200	0.19	115	19	8	80	8	0.9	2.8	<.05	<.05	0.08	2	37	82	67	2.2	13.0	1.1	3.61	14.0	187	130	57	0.030	0.044
28-Sep-83	P66	SS/DW	8.1	186	0.07	98	16	5	61	7	0.8	2.5	<.05	<.05	0.08	<1	32	73	60	<1	<5	<.4	<.01	14.9	173	170	3	0.005	0.008
02-Nov-83	P66	SS/DW	8.1	248	2.50	138	26	6	99	13	0.7	3.3	<.05	<.05	0.09	2	34	115	94		47.3	1.0	12.60	22.0				0.054	0.300
03-Nov-83	P66	SS/DW	8.1	214	0.08	122	22	5	76	10	0.8	3.0	<.05	<.05	0.08	2	40	84	69	<1	5.1	0.6	<.01	17.0	137	130	7	0.019	0.008
15-Mar-83	W1	LRC	8.4	561	0.28	310	58	18	219	25	1.0	4.3	0.40	<.05	0.12	25	48	257	222	1.6	43.7	3.5	0.47	54.0	340	320	20	0.120	0.030
10-May-83	W1	LRC	8.2	214	0.96	126	33	6	107	6	1.2	3.4	<.05	<.05	0.09	<1	10	139	114	1.6	64.2	9.8	11.00	28.0	985	220	765	0.012	0.400
27-Sep-83	W1	LRC	8.3	331	0.13	174	43	11	153	6	0.6	2.8	<.05	<.05	0.12	<1	23	182	149	<1	<5	1.8	2.86	38.0	191	180	11	0.005	<.006
02-Nov-83	W1	LRC	8.4	317	0.22	169	43	11	153	6	0.4	2.7	<.05	<.05	0.08	<1	29	164	141	<1	7.9	1.5	<.01	35.0	274	260	14	0.008	0.016
15-Mar-83	W2	LRC	7.9	675	0.29	355	65	14	220	46	1.4	4.1	<.05	<.05	0.10	56	50	249	204	2.5	55.4	15.0	2.30	52.0	440	420	20	0.210	0.095
10-May-83	W2	L	8.1	249	3.43	134	33	7	111	9	1.4	3.6	0.06	<.05	0.09	3	13	138	113	2.6	79.5	10.0	14.00	28.0	1009	260	749	0.065	0.350
10-May-83	W2	R	8.0	249	1.65	136	33	6	107	9	1.4	3.6	<.05	<.05	0.09	4	14	139	114	2.6	77.3	10.0	15.00	28.0	922	270	652	0.063	0.525
10-May-83	W2	C	8.1	250	1.24	135	34	6	110	8	1.4	3.3	0.06	<.05	0.09	4		138	113	3.0	74.7	9.6	13.00	28.0	975	250	725	0.065	0.525
27-Sep-83	W2	L	8.2	420	0.28	226	48	11	165	20	1.0	2.5	<.05	<.05	0.09	20	33	189	155	1.1	20.2	6.3	4.66	39.0	285	270	15	0.005	0.074
27-Sep-83	W2	R	8.2	419	0.29	223	48	11	165	19	1.0	2.7	<.05	<.05	0.09	19	32	188	154	1.3	20.2	6.4	1.09	40.0	275	250	25	0.006	0.044
27-Sep-83	W2	C	8.2	416	0.29	222	47	10	159	20	1.0	2.8	<.05	<.05	0.09	19	32	188	154	<1	20.2	6.5	3.78	40.0	296	280	16	0.007	0.036
02-Nov-83	W2	L	8.3	368	0.27	197	44	11	155	14	0.8	2.7	<.05	<.05	0.08	8	32	177	145	<1	16.1	3.9	0.29	36.0	255	240	15	0.013	0.030
02-Nov-83	W2	R	8.3	370	0.27	194	44	10	151	13	0.7	2.7	<.05	<.05	0.08	8	32	176	144	<1	16.1	3.9	4.38	35.0	251	240	11	0.016	0.034
15-Mar-83	S1	LRC	7.9	507	0.22	287	68	19	249	7	0.1	4.2	0.08	<.05	0.14	<1	88	210	172	<1	8.5	1.6	0.97	42.0	357	340	17	0.075	0.015
10-May-83	S1	LRC	7.5	262	2.51	157	34	8	118	6	0.9	3.6	<.05	<.05	0.10	<1	21	135	111	1.6	66.8	5.6	15.00	27.0	849	250	599	0.016	0.435
27-Sep-83	S1	LRC	8.2	333	0.16	179	42	12	154	5	0.5	2.9	<.05	<.05	0.09	<1	42	156	128	<1	<5	1.2	2.49	33.0	240	230	10	0.005	0.010
02-Nov-83	S1	LRC	8.4	344	0.76	199	43	13	161	5	0.5	3.1	<.05	<.05	0.12	<1	45	190	152	<1	10.6	2.2	0.53	32.0	314	260	54	0.010	0.052
15-Mar-83	S2	L	7.8	663	0.20	356	69	15	234	39	1.2	4.2	<.05	<.05	0.12	45	65	247	203	<1	38.8	12.0	0.95	52.0	429	420	9	0.130	0.065
15-Mar-83	S2	R	7.7	562	0.18	311	71	17	247	15	0.9	4.2	0.08	<.05	0.13	12	80	234	192	<1	16.3	4.2	0.72	50.0	372	360	12	0.065	0.025
10-May-83	S2	L	7.3	222	1.14	124	33	7	111	9	1.6	3.6	0.11	<.05	0.09	3	12	147	112	2.0	77.7	9.2	15.00	27.0	812	120	692	0.060	0.470
10-May-83	S2	R	7.2	261	2.02	138	35	8	129	6	0.9	3.6	0.07	<.05	0.10	<1	29	175	111	1.8	79.1	6.2	14.00	27.0	751	120	631	0.024	0.440
10-May-83	S2	C	7.4	256	1.31	138	34	7	114	8	1.2	3.4	0.10	<.05	0.10	2	18	136	112	1.8	67.2	7.6	13.00	27.0	809	110	589	0.076	0.415
27-Sep-83	S2	L	8.3	371	0.25	199	45	11	159	11	0.8	2.7	<.05	<.05	0.09	9	38	169	139	<1	8.6	3.6	2.66	36.0	255	240	15	0.007	0.026
27-Sep-83	S2	R	8.2	325	0.21	190	45	11	158	9	0.7	2.6	<.05	<.05	0.09	5	38	166	136	<1	9.1	2.1	2.17	35.0	242	230	12	0.006	0.014
27-Sep-83	S2	C	8.2	360	0.20	194	45	11	158	10	0.7	2.8	<.05	<.05	0.09	7	38	167	137	<1	7.1	3.0	3.00	36.0	221	210	11	0.005	0.018
02-Nov-83	S2	L	8.5	357	0.32	190	43	11	153	11	0.6	2.8	<.05	<.05	0.09	5	37	158	157	<1	14.3	3.3	0.10	33.0	280	260	20	0.010	0.028
02-Nov-83	S2	R	8.4	346	0.50	187	43	12	157	8	0.5	3.0	<.05	<.05	0.09	2	41	158	133	<1	11.6	2.4	0.27	33.0	376	260	36	0.007	0.040
15-Mar-83	S3	L	8.0	571	0.39	311	65	16	298	23	1.0	4.2	0.08	<.05	0.13	23	70	228	187	<1	24.1	6.5	1.40	48.0	343	330	13	0.110	0.045
15-Mar-83	S3	R	7.8	570	0.08	316	66	16	251	24	1.0	4.4	0.08	<.05	0.13	25	70	251	199	<1	22.2	6.6	<.01	50.0	380	370	10	0.099	0.040
10-May-83	S3	L	7.4	253	1.36	136	34	7	114	8	1.3	3.6	0.07	<.05	0.10	2	17	136	111	2.6	70.7	8.6	14.00	27.0	556	230	326	0.028	0.495
10-May-83	S3	R	8.2	255	1.39	137	34	7	114	7	1.2	3.6	0.07	<.05	0.10	2	17	140	115	2.0	69.0	9.7	13.00	30.0	859	240	619	0.022	0.575
10-May-83	S3	C	7.3	254	1.49	136	34	7	114	7	1.2	3.5	0.06	<.05	0.10	2	15	137	112	2.2	69.0	8.7	14.00	27.0	688	130	558	0.022	0.538
27-Sep-83	S3	L	8.2	361	0.26	195	47	10	159	10	0.7	2.9	<.05	<.05	0.09	6	37	171	140	<1	12.0	3.5	2.29	36.0	224	210	14	0.007	0.016
27-Sep-83	S3	R	8.2	354	0.22	197	48	10	161	11	0.7	3.1	<.05	<.05	0.09	6	36	173	142	<1	13.0	3.6	1.97	36.0	224	210	14	0.007	0.018
27-Sep-83	S3	C	8.2	355	0.24	191	45	10	154	10	0.7	3.0	<.05	<.05	0.09	6	35	171	140	<1	14.0	3.5	3.00	36.0	234	220	14	0.006	0.020
02-Nov-83	S3	L	8.5	354	0.42	189	43	12	157	9	0.6	2.8	<.05	<.05	0.09	3	38	161	132	<1	12.5	3.0	0.32	34.0	295	270	25	0.007	0.034
02-Nov-83	S3	R	8.4	354	0.40	189	44	12	159	9	0.6	2.8	<.05	<.05	0.09	3	38	161	138	<1	11.6	3.0	0.17	33.0	305	280	25	0.015	0.034
15-Mar-83	S4	L	7.9	573	0.22	320	69	17	262	21	1.0	4.6	0.07	<.05	0.13	19	75	240	197	<1	18.3	5.6	0.37	50.0	342	330	12	0.080	0.035
15-Mar-83	S4	R	7.9	587	0.15	322	69	16	238	23	1.0	4.2	0.07	<.05	0.13	23	75	232	191	<1	22.2	5.6	0.35	48.0	377	370	7	0.120	0.035
11-May-83	S4	L	8.2	256	1.18	136	33	7	111	8	1.5	3.5	<.05	<.05	0.10	2	16	139	113	1.2	50.8	9.1	16.00	27.0	938	310	628	0.041	0.460

02-Nov-83	S2	L	8.5	357	0.32	190	43	11	153	11	0.6	2.8	<.05	<.05	0.09	5	37	158	137	<1	14.3	3.3	0.10	33.0	280	260	20	0.010	0.028
02-Nov-83	S2	R	8.4	346	0.56	187	43	12	157	8	0.5	3.0	<.05	<.05	0.09	2	41	158	133	<1	11.6	2.4	0.27	33.0	316	260	36	0.007	0.040
15-Mar-83	S3	L	8.0	571	0.20	311	65	16	298	23	1.0	4.2	0.08	<.05	0.13	23	70	228	187	<1	24.1	6.5	1.40	48.0	343	330	13	0.110	0.645
15-Mar-83	S3	R	7.8	570	0.08	316	66	16	231	24	1.0	4.4	0.08	<.05	0.13	25	70	231	190	<1	22.2	6.6	<.01	50.0	380	370	10	0.099	0.640
10-May-83	S3	L	7.6	253	1.36	136	34	7	114	8	1.3	3.4	0.07	<.05	0.10	2	17	136	111	2.6	70.7	8.6	14.00	27.0	556	230	326	0.028	0.495
10-May-83	S3	R	8.2	255	1.39	137	34	7	114	7	1.2	3.6	0.07	<.05	0.10	2	17	140	115	2.0	69.0	9.7	13.00	30.0	859	240	619	0.022	0.575
10-May-83	S3	C	7.3	254	1.49	134	34	7	114	7	1.2	3.5	0.06	<.05	0.10	2	15	137	112	2.2	69.0	8.7	14.00	27.0	688	130	558	0.022	0.538
27-Sep-83	S3	L	8.2	361	0.26	195	47	10	159	10	0.7	2.9	<.05	<.05	0.09	6	37	171	140	<1	12.0	3.5	2.29	36.0	224	210	14	0.007	0.016
27-Sep-83	S3	R	8.2	354	0.32	197	48	10	161	11	0.7	3.1	<.05	<.05	0.09	6	36	173	142	<1	13.0	3.6	1.97	36.0	224	210	14	0.007	0.018
27-Sep-83	S3	C	8.2	355	0.24	191	45	10	154	10	0.7	3.0	<.05	<.05	0.09	6	35	171	140	<1	14.0	3.5	3.00	36.0	234	220	14	0.006	0.020
02-Nov-83	S3	L	8.5	354	0.42	189	43	12	157	9	0.6	3.1	<.05	<.05	0.09	3	38	161	139	<1	12.5	3.0	0.32	34.0	295	270	25	0.007	0.034
02-Nov-83	S3	R	8.4	354	0.40	189	44	12	159	9	0.6	2.8	<.05	<.05	0.09	3	38	161	138	<1	11.6	3.0	0.17	33.0	305	280	25	0.015	0.034
15-Mar-83	S4	L	7.9	573	0.22	320	69	17	242	21	1.0	4.6	0.07	<.05	0.13	19	75	240	197	<1	18.3	5.6	0.37	50.0	342	330	12	0.080	0.035
15-Mar-83	S4	R	7.9	587	0.15	322	69	16	238	23	1.0	4.2	0.07	<.05	0.13	23	75	232	191	<1	22.2	5.6	0.35	48.0	377	370	7	0.120	0.035
11-May-83	S4	L	8.2	256	1.18	136	33	7	111	8	1.5	3.5	<.05	<.05	0.10	2	16	138	113	1.2	50.8	9.1	16.00	27.0	938	310	628	0.041	0.460
11-May-83	S4	R	7.5	255	1.56	134	33	7	111	8	1.2	3.5	0.06	<.05	0.11	2	16	136	112	1.8	52.2	9.0	11.00	29.0	859	300	559	0.041	0.450
11-May-83	S4	C	7.6	250	2.65	132	32	7	109	8	1.2	3.4	<.05	<.05	0.10	2	15	135	111	1.6	50.4	8.7	14.00	28.0	879	320	559	0.044	0.440
28-Sep-83	S4	L	8.4	358	0.23	190	40	11	145	10	0.9	3.0	<.05	<.05	0.10	6	37	170	142	<1	13.9	3.8	0.59	34.7	288	270	18	<.002	0.020
28-Sep-83	S4	R	8.4	362	0.25	189	41	11	148	9	0.9	2.9	<.05	<.05	0.10	5	37	168	142	<1	9.4	3.8	0.42	34.7	304	290	14	0.003	0.020
28-Sep-83	S4	C	8.4	359	0.22	192	42	11	150	9	0.9	2.9	<.05	<.05	0.10	6	38	168	142	<1	10.3	4.1	0.28	34.7	285	270	15	<.002	0.020
02-Nov-83	S4	L	8.4	342	0.33	184	43	11	153	9	0.6	3.1	<.05	<.05	0.09	3	36	162	136	<1	11.6	3.0	0.09	32.0	262	240	22	0.007	0.028
02-Nov-83	S4	R	8.4	340	0.37	184	43	11	153	9	0.5	3.1	<.05	<.05	0.08	3	36	159	136	<1	15.2	3.1	0.09	33.0	269	250	19	0.007	0.028
15-Mar-83	S5	L	7.7	579	0.24	322	69	17	242	25	1.1	4.7	0.10	<.05	0.13	22	70	239	196	<1	21.1	6.1	0.55	51.0	494	480	14	0.110	0.040
15-Mar-83	S5	R	7.7	568	0.14	314	69	16	238	24	1.1	4.7	0.10	<.05	0.12	22	65	237	194	<1	22.2	6.0	0.50	51.0	399	390	9	0.160	0.040
11-May-83	S5	L	7.7	260	3.93	141	34	8	118	9	1.3	3.5	0.06	<.05	0.11	2	18	139	114	2.0	65.2	9.3	22.00	29.0	1136	300	836	0.039	0.650
11-May-83	S5	R	7.5	261	1.70	135	32	7	109	9	1.4	3.4	<.05	<.05	0.10	2	15	138	113	1.8	56.4	9.4	16.00	30.0	875	280	595	0.046	0.650
11-May-83	S5	C	7.5	260	3.92	137	33	7	111	9	1.3	3.5	0.06	<.05	0.11	2	17	138	113	1.8	62.5	9.3	19.00	29.0	1061	280	781	0.039	0.650
28-Sep-83	S5	L	8.5	342	0.35	189	44	10	151	10	0.9	3.0	<.05	<.05	0.10	5	34	163	140	<1	13.9	5.4	0.21	34.0	250	230	20	<.002	0.028
28-Sep-83	S5	R	8.4	340	0.40	185	41	10	144	10	0.9	3.0	<.05	<.05	0.10	4	33	169	139	<1	16.6	5.9	0.07	34.0	260	240	20	0.005	0.030
28-Sep-83	S5	C	8.4	339	0.36	184	42	10	146	10	0.9	3.0	<.05	<.05	0.10	4	33	111	139	<1	15.7	5.5	0.16	33.0	240	220	20	0.006	0.030
02-Nov-83	S5	L	8.4	328	0.49	179	41	11	148	8	0.6	3.2	<.05	<.05	0.08	3	35	158	134	<1	15.2	3.9	0.42	32.0	277	260	17	0.010	0.028
02-Nov-83	S5	R	8.3	329	0.44	180	43	11	153	9	0.7	3.2	<.05	<.05	0.08	3	33	162	133	<1	16.1	4.4	0.04	33.0	291	270	21	0.011	0.028
16-Mar-83	S6	L	7.9	568	0.17	321	68	16	236	25	1.1	4.7	0.07	<.05	0.14	22	70	240	197	<1	24.1	7.0	0.24	33.0	416	410	6	0.099	0.024
16-Mar-83	S6	R	7.9	572	0.19	318	70	17	245	24	1.1	4.8	<.05	<.05	0.13	22	65	241	197	<1	20.2	6.1	0.14	51.0	404	400	4	0.090	0.026
11-May-83	S6	L	7.4	262	3.70	133	31	7	106	8	1.3	3.3	<.05	<.05	0.10	2	15	139	114	1.6	66.1	8.0	16.00	30.0	1103	310	793	0.039	0.650
11-May-83	S6	R	7.5	262	1.29	138	32	8	115	8	1.4	3.4	<.05	<.05	0.10	2	17	139	114	2.0	63.9	9.2	21.00	30.0	1106	300	806	0.039	0.680
11-May-83	S6	C	7.5	262	2.60	136	32	8	113	8	1.4	3.3	0.06	<.05	0.10	2	16	139	114	2.2	64.3	9.3	12.00	30.0	1106	300	806	0.050	0.680
28-Sep-83	S6	L	8.4	331	0.36	182	41	10	144	9	0.9	3.0	<.05	<.05	0.10	4	32	167	139	<1	14.8	5.7	0.19	33.0	248	220	28	0.003	0.032
28-Sep-83	S6	R	8.4	335	0.37	183	40	10	141	10	1.0	3.0	<.05	<.05	0.10	4	34	166	139	<1	15.7	5.9	0.24	34.0	277	240	37	0.003	0.034
28-Sep-83	S6	C	8.4	340	0.29	187	41	10	144	13	1.1	3.0	<.05	<.05	0.10	4	34	166	139	<1	16.6	5.8	0.18	33.0	230	210	20	<.002	0.028
03-Nov-83	S6	L	8.4	328	0.40	178	40	11	145	9	0.6	3.2	<.05	<.05	0.08	3	35	160	132	<1	16.1	4.2	2.75	33.0	242	220	22	0.006	0.032
03-Nov-83	S6	R	8.3	331	0.32	177	40	11	145	9	0.7	3.2	<.05	<.05	0.08	2	34	161	132	<1	19.8	4.1	0.21	33.0	254	230	24	0.006	0.028
16-Mar-83	S7	L	7.9	577	0.20	318	69	17	242	25	1.1	4.7	0.07	<.05	0.14	22	65	241	197	<1	20.2	6.1	11.00	52.0	327	320	7	0.100	0.026
16-Mar-83	S7	R	7.8	572	0.20	322	70	17	245	24	1.1	4.6	0.07	<.05	0.13	22	70	239	196	<1	20.2	6.0	0.11	51.0	317	310	7	0.087	0.024
11-May-83	S7	L	8.3	269	1.97	157	38	10	136	9	2.8	4.4	0.08	<.05	0.10	6	21	142	117	1.8	64.8	8.7	18.00	31.0	1196	280	916	0.041	0.700
11-May-83	S7	R	8.3	267	1.60	143	34	7	114	9	1.4	3.5	<0.05	<.05	0.12	2	20	142	116	2.4	68.4	9.3	23.00	99.0	942	140	802	0.041	0.700
11-May-83	S7	C	8.3	264	1.17	142	33	8	115	8	1.4	3.4	0.06	<.05	0.11	2	20	142	116	3.0	71.5	9.2	18.00	31.0	1430	420	1010	0.039	0.750
28-Sep-83	S7	L	8.3	341	0.53	182	38	10	136	10	1.0	3.0	<.05	<.05	0.10	5	34	169	139	<1	15.7	6.1	0.37	34.0	299	260	39	<.002	0.040
28-Sep-83	S7	R	8.4	345	0.48	185	41	10	144	10	1.0	3.0	<.05	<.05	0.10	5	34	167	139	<1	20.2	6.1	0.48	34.0	269	240	29	0.006	0.036
28-Sep-83	S7	C	8.3	327	0.46	182	39	10	139	10	1.0	3.1	<.05	<.05	0.10	4	34	169	139	<1	15.7	6.1	0.29	34.0	263	230	33	<.002	0.038
03-Nov-83	S7	L	8.4	331	0.40	178	40	11	145	10	0.6	3.2	<.05	<.05	0.08	3	34	157	132	<1	17.1	4.0	0.13	32.0	266	240	26	0.006	0.032
03-Nov-83	S7	R	8.4	331	0.40	177	40	11	145	9	0.7	3.2	<.05	<.05	0.08	3	34	158	133	<1	18.0	4.4	0.40	31.0	226	200	26	0.006	0.032
17-Mar-83	P1	LRC	8.3	209	0.99	106	27	6	92	2	0.5	3.7	0.07	<.05	0.06	2	10	117	96	<1	6.5	2.3	2.50	28.0	163	120	43	0.005	0.040
12-May-83	P1	LRC	7.9	208	8.13	103	28	5	91	3	<.2	3.6	0.07	<.05	0.08	<1	14	105	86	<1	64.3	9.6	15.00	20.0	1180	200	980	0.021	0.850
29-Sep-83	P1	LRC	8.3	184	0.13	92	22	5	76	2	0.4	2.9	<.05	<.05	<.05	<1	10	104	85	<1	<5	2.3	0.28	20.8	134	120	14	0.005	0.016
03-Nov-83	P1	LRC	8.3	190	0.11	101	25	6	87	2	0.3	<.5	<.05	<.05	0.06	<1	13	108	88	<1	7.9	2.1	<.01	23.0	149	140	9	0.005	0.012
17-Mar-83	P2	L	8.2	212	1.38	106	28	6	95	2	0.5	4.0	<.05	<.05	<.05	<1	10	119	98	<1	10.4	2.2	3.20	24.0	209	140	69	<.002	0.074
17-Mar-83	P2	R	8.0	450	0.80	240	51	12	177	18	0.9	4.5	<.05	<.05	0.11	16	45	196	161	2.1	17.3	4.4	3.30	40.0	331	240	91	0.007	0.042
12-May-83	P2	L	7.9	210	6.68	107	28	5	91	3	0.9	3.5	<.05	<.05	0.08	<1	17	105	86	<1	68.8	9.1	17.00	20.0	1569	210	1359	0.027	1.100
12-May-83	P2	LC	7.9	207	5.33	106	28	5	91	4	0.9	3.5	0.06	<.05	0.08	<1	15	105	86	<1	65.2	9.1	23.00	20.0	1120	150	970	0.023	1.050
12-May-83	P2	RC	8.0	207	6.28	107	28	5	91	3	0.9	3.5	<.05	<.05	0.08	<1	17	105	87	<1	60.7	9.1	16.00	20.0	1118	190	928	0.022	0.850
12-May-83	P2	R	8.1	260	7.69	139	34	7	114	9	1.3	3.5	<.05	<.05	0.10	2	18	137	112	<1	65.2	10.0	13.00	27.0	1219	220	999	0.038	0.800
29-Sep-83	P2	L	8.3	191	0.11	96	25	5	83	3	0.4	2.9	<.05	<.05	0.07	<1	10	105	86	<1	7.5	3.2	0.52	21.0	164	150	14	0.003	0.016
29-Sep-83	P2	LC	8.3	180	0.11	94	24	5	81	2	0.4	3.0	<.05	<.05	0.06	<1	10	105	86	<1	<5	3.2	0.25	21.0	144	130	14	0.056	0.014
29-Sep-83	P2	RC	8.4	212	0.15	110	28	6	95	3	0.5	3.0	<.05	<.05	0.07	<1	14	117	96	<1	5.7	3.8	0.06	23.0	169	150	19	<.002	0.018
29-Sep-83	P2	R	8.4	277	0.35	148	37	8	125	6	0.8	3.0	<.05	<.05	0.08	2	24	140	117	<1	11.2	5.8	0.54	28.0	243	220	23	0.003	0.030
03-Nov-83	P2	L	8.4	194	0.09	101	26	6	90	2	0.3	2.9	<.05	<.05	0.06	<1	12	105	89	<1	9.7	2.2	0.13	23.0	120	110	10	0.004	0.010
03-Nov-83	P2	R	8.4	298	0.32	159	36	10	131	7	0.6	3.1	<.05	<.05	0.08	2	30	146	122	<1	15.2	3.5	0.17	31.0	232	210	22	0.006	0.028

Results as mg/L and metals as totals unless noted. Blanks indicate not analyzed. FEB=final effluent grab FEC=final effluent composite

APPENDIX 7 Other trace organic compounds tentatively identified by Alberta Environmental Centre, 1983

	MARCH				MAY		SEPTEMBER			NOVEMBER	
Sites:	P&GFE		W2	S5L	P&GFE		P&GFE		S5	P&GFE	W2
Day:	15th	16th	15th	15th	10th	11th	27th	28th	28th	3rd	2nd
	Approximate concentrations - $ug \cdot L^{-1}$										
$C_7H_{10}O$ isomers (MW 110)							1-5				
$C_9H_{12}O$ isomers (MW 136)	75-100	400-450			200-250						
$C_{10}H_{18}$ isomers (MW 138)	75-100	250-300									
$C_8H_{14}S$ isomers (MW 154)	1-5										
$C_{10}H_{16}$ isomer (MW 136)		25-50			200-250	50-75					
$C_{10}H_{12}$ isomers (MW 220)								200-350			
Substituted pyridine	1-5										
Alkyl subst pyridine (MW 189)	25-50										
Hydroxy subst. pyridine (MW 153)		5-10									
2-methyl pyridine		1-5									
Chloropyridine		1-5									
Dimethyl 2,4-hexadiene	1-5				10-25	1-5		1-5			
3-ethyl-2,5-dimethoxy 1,3-hexadiene	1-5										
Dimethyl ethyl cyclohexadiene	1-5										
Methoxy cyclohexadiene	1-5	10-25			10-25	1-5	10-25				
1 methyl-4-(iso-propyl)-1,4 cyclohexadiene		350-400									
Tetramethyl cyclohexadiene		100-150									
Methyl chloro cyclohexadiene					1-5	1-5	1-5	0.5-1			
Methoxy acetoxy cyclohexadiene							0.5-1				
Isopropyl methyl cyclohexadienol							0.5-1				
Methyl propylbenzene								0.5-1		0.5-1	
Dimethoxy dihydro benzene					5-10	1-5	1-5	1-5		1-5	
Trichloro methoxy ethoxy benzene (catechol)					1-5	1-5					
Dihydrodihydroxy benzene								1-5			

APPENDIX 7 Cont'd Other trace organic compounds tentatively identified by Alberta Environmental Centre, 1983

	MARCH				MAY		SEPTEMBER			NOVEMBER	
Sites:	P&GFE		W2	S5L	P&GFE		P&GFE		S5	P&GFE	W2
Day:	15th	16th	15th	15th	10th	11th	27th	28th	28th	3rd	2nd
Dimethoxy benzene		1-5									
Dimethyl benzyl	1-5	1-5			5-10		5-10	1-5		0/5-1	
Ethyl dimethyl benzene		1-5									
Methoxy ethoxy trichlorocatechol		5-10									
Aceto catechol											
Alkyl substituted benzyl alcohol (MW 160)							0.5-1			5-10	
Trimethyl-3-cylohexane -1-methanol					25-50	10-20					
Dimethyl benzyl alcohol	1-5						200-350	25-50			
Aromatic alcohol $C_9H_{12}O$ (MW 136)		100-150			25-50						
Dihydroxy phenyl ethanone	1-5										
Hydroxy dimethoxy phenyl ethanone	1-5										
Parazol ethanone		1-5									
1-(4-hydroxy-3-methoxy phenyl) ethanone		1-5									
Methyl phenyl ethanone		50-75			50-75						
Dimethyl cyclopentadiene	1-5	5-10									
Methyl benzamide	1-5										
Methoxy isopropyl phenol								1-5			
Methyl isopropyl phenol					10-25	5-10	10-25			0.5-1	
Methyl ethyl phenol	1-5										
2-methoxy phenol	5-10	10-25						0.5-1			
4-methoxy phenol	5-10	10-25									
Methoxy phenol											
Tetrachloromethoxy phenol	5-10	1-5			50-75	10-20	25-50	1-5		1-5	
					1-5	1-5					
t-butyl methyl phenol	5-10										
Substituted phenol (MW 168)	5-10										
Substituted phenol (MW 170)	1-5										

APPENDIX 7 Cont'd Other trace organic compounds tentatively identified by Alberta Environmental Centre, 1983

	MARCH				MAY		SEPTEMBER			NOVEMBER	
Sites:	P&GFE		W2	S5L	P&GFE		P&GFE		S5	P&GFE	W2
Day:	15th	16th	15th	15th	10th	11th	27th	28th	28th	3rd	2nd
Dichlorodimethyl sulfone	10-15	10-25			50-75	30-40	25-50	5-10		10-50	0.01-0.1
Dimethyl sulfone					5-10	1-5					
2-methyl 2-cyclopentene-1-one		1-5									
3-methyl 2-cyclopentene-1-one		1-5									
Methyl cyclopentenone							1-5				
$C_9H_{12}O$ aromatic organic (MW 136)						75-100					
Monochloro subst. organic (MW 122)					5-10	1-5	1-5				
Methoxy subst. organic (MW 136)						30-40		0.5-1			
Dicarboxylic organic (MW 188)		1-5									
Monochloro aromatic organic (MW >210)				.01-0.1							
Dichloro propyl subst. organic (MW 186)					5-10	5-10					
$C_8H_{15}NO$ organic (MW 141)								0.5-1			
Dichlorofluoro organic (MW >136)										50-100	
Hydrocarbon (MW 124)							0.5-1				
Hydrocarbon (MW 138)							1-5				
Hydrocarbon (MW 160)							0.5-1				
Hydrocarbons (MW 180-210)							1-5				
Polycyclic hydrocarbon $C_{12}H_8$ (MW 152)							25-50				
Trimethyl bicyclo (2.2.1) heptanone					25-50	1-5		0.5-1			
Cyclohexenone					5-10						
Cyclohexanone						1-5	0.5-1				
Subst. cyclohexene (MW 152)					10-25	5-10					
Dimethyl cyclohexene								1-5		1-5	
Isopropyl methyl cyclohexene-1-one							0.5-1				
Cyclohexane		25-50									

APPENDIX 7 Concluded Other trace organic compounds tentatively identified by Alberta Environmental Centre, 1983

	MARCH				MAY		SEPTEMBER			NOVEMBER	
Sites:	P&GFE		W2	S5L	P&GFE		P&GFE		S5	P&GFE	W2
Day:	15th	16th	15th	15th	10th	11th	27th	28th	28th	3rd	2nd
Xylene			.01-0.1								
o-Xylene				0.1							
m-xylene				0.2							
p-xylene				0.8							
$C_{10}H_{12}O$ aromatic (MW = 136)											0.01-0.1
Hydroxy substituted aromatic $C_8H_8O_4$					5-10			0.5-1			
$C_8H_8O_2$ aromatic acid (MW=136)				100-150	75-100						
4-chloro benzoic acid						1-5					
Alkyl syringol $C_{11}H_{16}O_3$ (MW 196)							1-5				
Cyclo hexanyl methyl ester							5-10				
Phenyl acetate							5-10				
Methoxy fluorene										1-5	
Polypropylene glycol methyl ether (MW 300-450)									50-100		
Isopropyl methyl cyclohexeneol					1-5						
Trichloroguaiacol							0.5-1	0.5-1		0.5-1	
Guaiacol								1-5		5-10	
Dimethyl hexadrene										1-5	
Isopropyl thiophene								1-5			
Propyl thiophene							10-25				
Diethyl thiophene	1-5										
Veratrole								1-5		1-5	
Total	315	1,595	0 1	1.2	1,015	398	489	357	75	141	0.1

Results as $_{1}g \cdot L^{-1}$. P&GFE = Procter and Gamble final effluent. L = left downstream bank; R = right downsteam bank. Other river sites were cross channel composite samples.
The above compounds were recoverable and identifiable. Other organic compounds may also be present (see also Table 8).
Totals are calculated from mid-range values.
Note that the following sites were also analyzed but had no detectable trace organic compounds: March 15, Site S5R; May 10th, Site W2; May 11th, Site S5; May 12th, Site P2; September 27th, Site W2; September 29th, Site P2; November 2nd, Site S5; November 3, Site P2.

APPENDIX 8 City of Grande Pairie sewage lagoon grab sample, 11 April 1983

Parameter	$mg \cdot L^{-1}$ (unless noted)
pH	7.32
Conductivity (µS/cm)	1310
Iron	0.5
Nitrate + Nitrite Nitrogen	<0.2
Calcium	69
Chloride	165
Total Dissolved Solids	818
Biochemical Oxygen Demand (5 day) (BOD)	86
Total Residue (TR)	847
Total Residue Fixed (TRF)	548
Total Nonfiltrable Residue (NFR)	15
Fixed Nonfiltrable Residue (NFRF)	<1
Chemical Oxygen Demand (COD)	195
Ammonia Nitrogen	34.8
Total Phosphate - P	9.8
Total Kjeldahl Nitrogen (TKN)	40.0
Total Organic Carbon (TOC)	285
Total Inorganic Carbon (TIC)	45
Oil & Grease (Freon Extractables)	4
Phenols	0.092
Cobalt	<0.02
Copper	0.09
Nickel	<0.05
Cadmium	<0.01
Lead	<0.05
Zinc	0.06
Aluminum	0.37
Arsenic	<0.001
Selenium	0.002
Manganese	0.17
Chromium	<0.03
Vanadium	0.01
Molybdenum	<0.13

Data from City of Grande Prairie

APPENDIX 9 Water quality measured in the field, 1983

Site	March 14-17 Temperature °C	pH	Oxygen mg·L^{-1}	Conductance µSecm^{-1}	November 2-3 Temperature °C
			08101F		
W1					4.0
WRR					4.0
WBR					4.0
W2	0.2	8.2	10.7	662	4.0 L 4.0 R
S1	0.1	7.6	11.2	488	4.0
S2R	0.3	7.3	10.0	547	5.0
L	0.0	7.3	9.5	647	5.0
S3R	0.0	7.4	10.4	560	5.0
L	0.0	7.5	10.4	559	5.0
S4R	0.1	7.4	9.7	576	5.0
L	0.1	7.1	10.2	579	5.0
S5R	0.1	7.3	9.9	554	5.0
L	0.0	7.3	9.6	563	5.0
S6R	0.0	7.9	9.4	554	3.0
L	0.1	7.2	9.3	557	3.0
S7R	0.0	6.8	9.4	566	4.0
L	0.1	7.1	9.2	561	3.0
P1	0.1	7.3	12.0	195	7.0
P2R	0.0	7.0	10.2	428	4.0
L	0.1	7.3	12.0	195	6.0

S5 Centre (00A107GJ0001)

	Oxygen mg·L^{-1}	08101L % Saturation
January 10	12.6	89
February 15	11.9	84
March 15	12.0	85
April 24	11.9	100
May 17	9.9	93
June 13	10.7	102
July 19	10.0	104
August 15	8.7	93
September 12	10.5	96

APPENDIX 10 Organic priority pollutants included in the trace organic contaminant analysis by Alberta Environmental Centre, 1983.

I. Extractables
(detection limit 1 $\mu g \cdot L^{-1}$)

ACID GROUPS

Benzoic Acid
4-Chloro-m-cresol
2-Chlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
4,6-Dinitro-o-cresol
2,4-Dinitrophenol
Hexadecanoic acid
2-Nitrophenol
4-Nitrophenol
Pentachlorophenol
Phenol
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

BASE NEUTRAL GROUP

Acenaphthene
Acenaphthylene
Anthracene
Benz(a)anthracene
Benzo(k)fluoranthene
Benzo(ghi)perylene
Benzo(a)pyrene
Chrysene
Dibenz(ah)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Perylene
Phenanthrene
Pyrene

Chloroorganics

Chlorobenzene
2-Chloronaphthalene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
1,2,4-Trichlorobenzene

Nitroaromatics

Benzidine
3,3-Dichlorobenzidine
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodi-n-propylamine

Halo Ethers

4-Bromophenyl phenyl ether
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
2-Chloroethyl vinyl ether
4-Chlorophenyl phenyl ether

Phthalate Esters

Butylbenzyl phthalate
Di-n-butylphthalate
Diethylphthalate
Dimethylphthalate
Di-n-octylphthalate
Bis(2-ethylhexyl)phthalate

II. Volatiles (Purgeables)
detection limit 0.1 $\mu g \cdot L^{-1}$

Benzene
Bromodichloromethane
Bromoform
Carbon tetrachloride
Chlorobenzene
Chloroform
Dibromochloromethane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,1-Dichloroethane
1,1-Dichloroethylene
trans-1,2-Dichloroethylene
trans-1,3-Dichloropropylene
Ethyl benzene
Methylene chloride
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
Trichloroethylene
Trichlorofluoromethane
o-Xylene
m-Xylene
p-Xylene

APPENDIX 11 Bacteria data, 1983

Site	16 - 17 March				10 -11 May			
	T.C.	F.C.	F.S.	S.P.C.	T.C.	F.C.	F.S.	S.P.C.
P & G								
FEG	900	410	190	13×10^6	5,600	210	500	10^7
FEG	1,200	600	<10	24×10^6	500	<10	700	280,000
FEC					300	100	1,500	1.1×10^6
SS/CW	4	2	2	4,400	400	280	10	1.1×10^6
SS/CW	<2	<2	6	3,100	100	<10	100	4,000
W1	16	2	<2	80	500	10	90	2,900
W2L					8,000	90	170	170,000
R					800	50	120	
C	36	2	34	330,000	5,300	10	90	
S1	34	<2	<1	93	80	<10	70	12,000
S2L	32	2	12	160,000	1,400	20	70	
R	40	<2	4	42,000	220	<10	70	
C					2,500	10	90	14,000
S3L	26	2	22	150,000	13,000	50	120	
R	20	2	10	110,000	1,110	10	60	
C					5,300	20	80	
S4L	30	<2	4	110,000	900	10	80	6,000
R	32	<2	<2	800	430	20	90	4,800
C					500	70	110	6,200
S5L	12	<2	2	46,000	400	10	120	2,800
R	20	2	4	3,300	300	10	110	5,500
C					500	10	90	6,500
S6L	14	<2	2	12,000	200	10	30	8,400
R	18	<2	6	9,700	400	10	50	2,100
C					900	20	60	5,700
S7L	<2	<2	<2	23,000	700	30	90	2,100
R	<2	<2	<2	10,000	500	20	80	2,400
C					200	10	60	5,800
P1	40	2	4	200	400	10	140	1,500
P2L	470	8	14	150	800	40	120	1,700
LC					500	20	90	1,200
RC					300	<10	120	2,300
R	4,900	120	2,500	8,500	600	10	40	14,000

APPENDIX 11 cont'd Bacteria data, 1983

	27-28 September				2-3 November	
	T.C.	F.C.	F.S.	S.P.C.	T.C.	F.C.
P & G						
FEG	42,000	2,500	20	3.5×10^6	240,000	2
FEG	23,000	2,700	3,300	2.1×10^6	16	2
FEC				16	9	
SS/CW	4	2	4	2,400	540	110
SS/CW	<2	<2	8	300	16	<2
W1	40	8	6	60	460	2
W2L	130	90	<2	5,000	170	7
R	170	40	2	2,500	130	2
C	140	50	2	15,000		
S1	16	<2	<2	40	350	9
S2L	34	12	2	3,500	540	2
R	60	<2	<2	1,900	920	2
C	28	6	<2	1,000		
S3L	50	4	6	170	49	2
R	44	6	<2	5,200	240	<2
C	110	10	<2	3,100		
S4L	54	<2	<2	3,600	350	2
R	30	2	<2	6,400	130	2
C	26	2	2	16,000		
S5L	50	2	2	3,800	110	<2
R	48	2	2	6,100	110	2
C	60	4	6	1,700		
S6L	54	2	2	2,500	49	<2
R	100	4	2	3,000	49	<2
C	88	<2	2	2,900		
S7L	50	<2	<2	2,400	130	2
R	50	2	2	1,400	79	2
C	62	<2	<2	2,200		
P1	72	2	2	80	9	2
P2L				16+	<2	
LC	64	6	4	110		
RC	76	<2	12	530		
R	130	6	<2	1,400	16	<2

T.C. : Total Coliforms /100 mL
F.C. : Faecal Coliforms /100 mL
F.S. : Faecal Streptococci /100 mL
S.P.C.: Standard Plate Count /1.0 mL

APPENDIX 12 Loading data for licence parameters, pulp mill final effluent, 1983.

Parameter		10 May	27 September	2 November
Discharge* -	$m^3 \cdot d^{-1}$	47,100	54,900	56,300
BOD	$mg \cdot L^{-1}$	33.3	41.5	35.0
	$kg \cdot d^{-1}$	1,570	2,280	1,970
COD	$mg \cdot L^{-1}$	744	981	not
	$kg \cdot d^{-1}$	35,000	53,900	licenced
Non filterable residue	$mg \cdot L^{-1}$	214	338	60
	$kg \cdot d^{-1}$	10,100	18,600	3,380

*Discharge from Procter and Gamble reports (Appendix 4)
Concentration data from composite samples of this study (Appendix 6)

APPENDIX 13 Algal Growth Potential in Selenestrum capricornutum Printz algal assays, 1983.

Site	May 10 - 12		September 27 - 29		November 2 - 3	
	AGP	S	AGP	S	AGP	S
W1	489,000	400,000	33,800	1,660	128,000	31,600
WRR	397,000	197,000	48,600	10,000	58,300	19,700
WBR	370,000	122,000	38,300	4,200	52,300	4,190
W2-R	489,000	66,000	108,000	4,150	82,600	13,900
-C	604,000	74,000	105,000	5,950		
-L	554,000	46,000	74,000	14,400	78,000	10,800
S1	995,000	59,000	6,120	2,840	32,500	15,800
S2-R	603,000	252,000	17,400	3,700	17,400	7,820
-C	866,000	144,000	26,200	3,520		
-L	535,000	151,000	38,300	635	23,700	5,530
S3-R	734,000	185,000	40,300	17,600	9,320	7,570
-C	356,000	70,000	30,800	11,900		
-L	189,000	35,000	19,700	3,310	10,400	7,860
S4-R	450,000	212,000	32,500	7,010	20,900	2,950
-C	560,000	92,400	36,500	17,300		
-L	296,000	211,000	20,600	4,800	28,000	3,330
S5-R	697,000	190,000	43,500	17,600	28,700	6,610
-C	366,000	40,600	38,400	13,200		
-L	520,000	216,000	41,900	4,450	20,500	12,400
S6-R	227,000	118,000	41,500	8,700	30,800	8,230
-C	508,000	41,700	66,200	3,910		
-L	470,000	202,000	55,200	5,410	47,200	12,200
S7-R	300,000	72,000	34,700	18,700	49,900	2,880
-C	266,000	156,000	43,000	8,070		
-L	273,000	104,000	31,700	16,700	32,600	3,520
P1	208,000	175,000	2,000	969	10,100	1,500
P2-R	108,000	43,700	16,700	5,110	37,900	6,670
-RC	293,000	138,000	8,590	3,940		
-LC	370,000	103,000	8,470	2,020		
-L	381,000	278,000	8,200	2,410	9,660	437

Results as cells/mL. AGP = algal growth potential, mean of 3 assays.
S = standard deviation. Blanks indicate not analyzed.

APPENDIX 14 Wapiti, Smoky, and Peace Rivers, May 9 - 12, 1983:
Mean Numbers for Major Zoobenthic Variables

SITE	NEMATODA		OLIGOCHAETA		CRUSTACEA		EPHEMEROPTERA		TRICHOPTERA		PLECOPTERA		CHIRONOMIDAE		MISC. DIPTERA		OTHERS		MEAN TOTAL	SE	MEAN NO. TAXA
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%			
W1R	8	3	2	0.9	51	12	10	4	0.6	0.2	2	0.7	194	76	5	2	2	0.8	254	36	22
W1L	10	5	22	10	23	11	8	4	0.0	0.0	0.4	0.2	137	66	7	4	2	1.0	209	28	24
W2R	8	1	2	0.3	345	58	4	0.6	0.0	0.0	0.0	0.0	231	39	2	0.3	1	0.2	592	47	16
W2L	19	3	9	1.5	211	34	1	0.2	0.6	0.1	0.2	0.003	381	61	3	0.4	2	0.3	626	54	18
S1R	19	20	4	4	11	12	1	1.5	0.0	0.0	1	1	58	61	0	0.0	0.4	0.4	95	12	11
S1L	2	5	1	3	6	13	4	9	0.0	0.0	0.0	0.0	32	69	0.2	0.4	0.2	0.4	46	6	11
S2R	2	1	1	0.8	44	24	0.4	0.2	0.2	0.1	0.0	0.0	132	73	0.2	0.1	0.2	0.1	181	27	11
S2L	5	2	5	2	168	73	1	0.4	0.0	0.0	0.0	0.0	50	22	1	0.5	1	0.5	230	27	15
S3R	6	1	2	0.3	403	79	1	0.3	0.2	0.004	0.0	0.0	94	19	3	0.6	1	0.2	510	49	15
S3L	7	2	2	0.5	353	85	0.4	0.1	0.0	0.0	0.6	0.1	51	12	1	0.2	1	0.3	415	33	13
S4R	4	2	4	1.5	181	73	1	0.2	0.2	0.1	0.2	0.1	58	23	0.8	0.3	0.2	0.1	248	28	14
S4L	4	1	3	0.9	255	75	2	0.6	0.0	0.0	2	0.7	71	21	1	0.3	0.4	0.1	339	23	15
S5R	1	1	1	0.8	97	76	0.4	0.3	0.0	0.0	0.0	0.0	26	21	0.2	0.2	0.8	0.6	127	5	10
S5L	2	0.8	1	0.4	263	89	0.4	0.1	0.2	0.1	3	0.9	23	8	3	1.2	0.2	0.1	296	25	13
S6R	2	2	1	1.4	63	62	1	1	0.0	0.0	0.6	0.6	31	31	1	1.0	0.8	0.8	101	16	14
S6L	3	3	1	1.2	84	72	0.3	0.7	0.0	0.0	0.6	0.5	27	23	0.6	0.5	0.0	0.0	117	14	12
S7R	10	3	1	0.4	65	21	2	0.5	0.0	0.0	2	0.6	228	73	2	0.6	4	1	314	47	14
S7L	4	4	1	1.4	27	26	1	1	0.0	0.0	0.2	0.2	65	65	0.6	0.6	1	1	101	9	10
P1R	8	6	15	12	0.6	46	3	2	0.8	0.6	5	4	26	20	2	1.5	10	8	130	9	18
P1L	6	6	19	16	68	55	1	0.5	0.8	0.6	0.2	0.2	16	13	2	1.3	11	9	124	5	17
P2R	3	4	2	2.8	55	77	1	1.7	0.0	0.0	0.0	0.0	3	13	0.4	0.6.	0.6	0.8	71	6	11
P2L	11	10	20	18	34	35	2	1.7	0.2	0.2	1	0.9	28	25	2	2	7	6	109	7	17

Mean numbers are for the 5 replicate samples per site. Percentages are of the mean total per site.
SE = Standard Error

APPENDIX 15 Wapiti, Smoky, and Peace Rivers, September 27 - 29, 1983:
Mean Numbers for Major Zoobenthic Variables

SITE	NEMATODA		OLIGOCHAETA		CRUSTACEA		EPHEMEROPTERA		TRICHOPTERA		PLECOPTERA		CHIRONOMIDAE		MISC. DIPTERA		OTHERS		MEAN TOTAL	SE	MEAN NO. TAXA
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%			
W1R	0.6	0.4	2	2	0.6	0.4	13	9	0.0	0.0	45	31	76	53	6	4	0.2	0.1	143	12	16
W1L	1	0.3	12	3	0.2	0.05	79	22	0.4	0.1	153	42	113	31	5	1	3	0.7	367	60	20
W2R	47	3	529	30	756	44	7	0.1	1	0.1	3	0.2	341	20	10	0.6	44	3	1738	477	21
W2L	59	2	2245	70	100	3	32	1	2	0.1	77	2	679	21	3	0.1	0.8	0.03	3198	368	22
S1R	3	2	1	1	5	3	4	2	0.0	0.0	33	17	142	72	3	2	5	3	196	33	14
S1L	6	2	6	2	5	2	29	11	0.0	0.0	83	31	136	50	4	2	3	1	272	42	18
S2R	10	4	39	15	21	8	6	2	0.0	0.0	7	3	172	67	1	0.6	0.4	0.2	257	45	13
S2L	36	3	208	16	8	0.6	41	3	6	0.5	446	34	537	42	12	1	0.2	0.02	1293	157	22
S3R	22	4	45	9	7	1	25	5	0.2	0.04	68	14	327	66	2	0.4	0.8	0.2	496	49	23
S3L	22	4	57	10	6	1	27	5	2	0.3	122	21	328	57	1	0.2	11	2	577	24	23
S4R	15	2	30	5	3	0.6	25	4	0.0	0.0	113	18	429	70	0.6	0.1	1	0.2	617	77	21
S4L	7	2	25	8	0.2	0.1	7	2	0.2	0.1	75	25	181	61	2	0.5	2	0.5	298	79	17
S5R	11	4	20	7	5	2	13	5	0.2	1	42	15	186	67	0.6	0.2	1	0.4	278	43	20
S5L	0.2	2	5	6	0.4	0.5	6	8	0.2	0.3	7	9	56	75	0.2	0.3	0.6	0.8	75	14	12
S6R	1	2	2	3	0.8	1.2	11	16	0.8	1.2	20	30	32	47	0.0	0.0	0.0	0.0	68	11	14
S6L	3	3	15	13	0.4	0.4	9	8	0.4	0.4	15	13	68	59	2	1	2	1.6	114	7	17
S7R	16	7	4	2	15	7	12	5	2	1	13	6	147	68	9	4	1	0.5	217	27	19
S7L	2	1	3	2	0.8	0.5	4	2	0.0	0.0	6	3	156	91	0.2	0.1	0.2	0.1	172	11	9
P1R	15	8	95	51	36	19	0.8	0.4	0.0	0.0	6	3	6	3	0.6	0.3	28	15	188	23	15
P1L	6	6	26	15	54	31	6	3	0.2	0.1	14	8	32	19	0.8	0.5	34	20	172	17	19
P2R	9	7	25	18	20	14	5	4	0.0	0.0	30	22	27	19	3	2	21	15	141	42	17
P2L	5	4	28	24	22	19	1	1	0.0	0.0	3	3	50	44	0.6	0.5	5	5	115	17	15

Mean numbers are for the 5 replicate samples per site. Percentages are of the mean total per site.
SE = Standard Error